CHEMICAL ESSAYS.

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MDCCLXXXVI.

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PRE-

PREFACE.

ABOVE two thouſand copies of the former volumes of my Chemical Eſſays have been ſold, in leſs than five years. I mention not this circumſtance out of vanity, or as if I thought it contained any proof of their merit; but I produce it as a ſolid proof, of the diſpoſition of the Public to become acquainted with chemical Subjects, when they are treated in a popular way. This diſpoſition has been long prevalent in foreign countries; it ſeems to be gaining ground in our own; and if I have endeavoured to contribute a little towards its eſtabliſhment amongſt us, I hope the utility of the deſign will plead my excuſe with thoſe who, in the ſeverity of their judgments, may think, that I have contributed more than, from the nature of my Profeſſion and Situation, I ought to have done.

When I was elected Profeſſor of Divinity in 1771, I determined to abandon for ever the Study of Chemiſtry; and I did abandon it for ſeveral years: but the — *veteris veſtigia flammæ* — ſtill continued to delight me, and at length ſeduced me from my purpoſe. When I was made a Biſhop in 1782, I again determined to quit my favourite purſuit; the volume which I now offer to the Public is a ſad proof of the imbecility of my reſolution. I have on this day, however, offered a ſacrifice to other people's notions, I confeſs, rather than to my own opinion of *Epiſcopal Decorum*—I have deſtroyed all my chemical Manuſcripts.—A proſpect of returning health might have perſuaded me to purſue this delightful ſcience; but I have now certainly done with it for ever; at leaſt I have taken the moſt effectual ſtep I could to wean myſelf from an attachment to it, for with the holy zeal of the Idolaters of old, who had been addicted to *curious arts*—*I have burned my books.*—I will have one word more, however, at parting.

I have ſpent the beſt part of my life in this Univerſity; and have not been wholly incurious in obſerving what, I thought, were either excellencies or defects in our mode of Education. I mean not on this occaſion to enlarge upon either, but ſimply to take the liberty of ſuggeſting an hint, which has often engaged my attention. The hint reſpects — *The Utility of an Academic Inſtitution for inſtructing young Men of Rank and Fortune in the Elements of Agriculture; in the Principles of Commerce; and in the Knowledge of our Manufactures.*

This kind of ſtudy would agreeably ſolicit, and might probably ſecure, the Attention of that part of our Youth, which, in being exempted from the diſcipline of Scholaſtic Exerciſes, has abundant leiſure for other purſuits; which, in being born to opulence, is (I will ſay) unhappily deprived of one of the ſtrongeſt incentives to intellectual Exertion —

narrowneſs of fortune; — it would prepare them for becoming, at a proper age, intelligent Legiſlators of their Country; and it would inſpire them with ſuch a taſte for Huſbandry, as might conſtitute the chief felicity of their future lives.

When the Treaty with *Ireland* was agitated laſt year in Parliament, the utility of a comprehenſive knowledge of our commerce and manufactures was perfectly underſtood, both by thoſe who poſſeſſed it, and by thoſe who lamented their want of it. The commerce of Wool, Corn, Cotton, Hemp, Flax, Silk, Beer, Wine, Spirits, Salts, Sugar, Tar, Glaſs, Earthen Ware, Iron, Copper, Lead, Tin, &c. &c. are ſubjects of great importance to this Country, and it is humbly apprehended, that they are ſubjects alſo on which there are but few perſons in either houſe of Parliament, who have had an opportunity of being properly inſtructed, during the courſe of their Education.

Davenant, *Child*, *Poſtlethwayte*, *Anderſon*, and a great many other eminent writers on Trade and Commerce, would ſupply ample Materials for a Syſtem of Lectures, equally uſeful and entertaining. But as the attention of young men to abſtract ſpeculations is apt to flag, unleſs the ſubject be enlivened by a reference to the Senſes, together with the commercial Account, I ſhould think there might properly be given, both the Natural Hiſtory, and the Chemical Analyſis of the various objects which may fall within the comprehenſion of ſuch a plan.

My own notion, indeed, of National Improvement, Security, and Happineſs, tends not ſo much to the extending of our commerce, or the increaſing the number of our manufacturers; as to the increaſing of an hardy and, comparatively ſpeaking, innocent Race of Peaſants, by making Corn to grow on Millions of Acres of Land, where none has ever grown before. Let us but once have as many Britons in the Kingdom, as the well cultivated Lands of Great Britain are able to ſuſtain, and we ſhall have little to regret in the loſs of *America*; nothing to apprehend from the *partitioning* policy of all the continental Deſpots in Europe. I enter not into the queſtion concerning the population of the country; whether the Inhabitants of the Kingdom are more or fewer now than they were a century ago, cannot be conjectured with any great probability from the ſurveys of particular diſtricts, but the real number may be known with little difficulty, whenever the Legiſlature ſhall be deſirous of obtaining information on the Subject: for the Kingdom being divided into Counties, and the Counties into Pariſhes, &c. an actual Enumeration of the Inhabitants might be made every ten years, by the Miniſters and Church-wardens of the ſeveral Pariſhes, with as much certainty as the nature of the ſubject, conſidered in a political light, would require. But whatever may be the preſent number of the Inhabitants of Great Britain, there is no one who has thought upon the ſubject, but muſt admit, that were our Lands brought to their proper State of Cultivation, they would afford maintenance to twice as many as at preſent exiſt in the Country. In thus fixing the Baſis of National Strength, in the improved Cultivation of our Lands, I am far from inſinuating, that Manufactures and Agriculture cannot ſubſiſt in an eminent degree of perfection together: on the contrary, I conſider them as mutually ſubſervient to each other, and am quite aware, that in the preſent ſtate of the Finance of this Kingdom, our Commerce ought to be cheriſhed with ſingular Indulgence. Nor ſhall we ſufficiently avail ourſelves of the ineſtimable Advantage of an Inſular Situation, if we do not conſider our Glory and our Safety as cloſely connected with the Number of our Seamen; and every child in Politics muſt know, that the number of our Seamen will ever be proportioned to the extent of our foreign, and domeſtic Commerce.

Of all the Amuſements or Employments in which Country Gentlemen are engaged, that of ſuperintending with intelligence the cultivation of a Farm is one of the moſt uſeful to the Community, as well as to the Individual who applies himſelf to it. Great Improvements have been made in Agriculture within the laſt fifty years: there is a chaos of printed Information on the Subject, which wants to be digeſted into form, in order to be made generally uſeful. The ſeveral Agricultural Societies, which have been eſtabliſhed by Gentlemen in different parts of the Kingdom,

dom, have done great Service; we owe to their endeavours and to the patriotic Exertions of one deſerving Citizen *, the preſent flouriſhing condition of our Huſbandry; but far more Gentlemen would, probably, have been induced to turn their thoughts that way, and all of them with better proſpects of ſucceeding in their inquiries, had they, in their youth, been carefully inſtructed in the *Principles of Vegetation*, in the *Chemical Qualities of Soils*, and in the *Natures and Uſes of different Manures.* — But I mean only to give a hint concerning an Inſtitution, which I have no manner of expectation of ſeeing eſtabliſhed, though I am fully perſuaded it would be both a public benefit, and highly uſeful to that

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* Arthur Young, Eſq;

Claſs of Perſons of whoſe Education I have been ſpeaking.

Young Men of Fortune feel not the want of perſonal Merit during the ſhort time which they ſpend at the Univerſities: they ſee Conſequence and Reſpect, it is true, annexed in thoſe Seminaries to Learning and Talents, but in the world they ſee little reſpected but Wealth; and poſſeſſing that, or expecting to poſſeſs it from their Anceſtors, they are eaſily allured by the Indolence which is natural to the Human Species, and by the Improvidence which is incident to their time of life, to ſhrink from the taſk of acquiring accompliſhments really honourable, really uſeful, and really their own. When they are called to the Legiſlation of their Country, or when they become Maſters of families, or are in any way ſettled, as it is called, in the world, then they begin to be ſenſible of the deficiencies of their perſonal Acquirements; they ceaſe not to lament through life their own want of foreſight, in neglecting the Opportunities of Improvement which were offered to them in the Univerſities, or the Supineneſs of thoſe who had the care of their Education, in not having ſtimulated them to the purſuit of uſeful ſtudies. This is only the general account, for there are ſome to whom it is not applicable; and though it may not be in our power to counteract the indolent propenſities of Nature, or to ſtem the torrent of faſhionable levities, to which young Men, by a too early introduction into the world, are fatally expoſed; yet it is our Duty to endeavour to augment the number of thoſe, who, at ſo green an Age, have learned to make a proper eſtimate of their future intellectual wants; and I know no method better adapted to effectuate this deſirable End, than to propoſe to them entertaining Objects of Study, of which they may clearly perceive the immediate utility, in the application of the knowledge they attain, to the important purpoſes of Legiſlative Policy and Rural Œconomics.

I ſhall be told, that there is not time for this; that even Claſſics, Ethics, Mathematics, and, God forbid I ſhould omit what is of infinitely more value than all the reſt, the Inſtitutes of Chriſtianity, can be but ſuperficially attended to during the few Months which theſe young Men reſide in the Univerſities. I will not attempt to obviate this Objection by making an invidious compariſon between the Utility of Claſſics, Ethics, or Mathematics, and the branches of Study here hinted at; I admit the force of it in its full extent. But I beg leave to aſk, whoſe fault is it that young Men of Fortune ſtay not more years with us, and reſide not amongſt us more months in every year? Why muſt they, as ſoon as they have huddled through ſix or eight Terms, be hurried abroad as if it were from an Apprehenſion, that they have Learned as much as an Engliſh Univerſity can teach them? Foreign Travel is of great uſe, when it is undertaken by Men who have learned to bring their paſſions under the control of Reaſon and Religion; who have had ſome Experience in Life, acquired ſome Knowledge of the Manufactures, Policy, Revenues, and Reſources of their own country; the acquaintance of ſuch Men will be ſought after by perſons of Character and Learning in every country they paſs through, they will be in a condition to receive, becauſe they will poſſeſs the Ability of communicating Knowledge. But the preſent mode of ſending our young Men into *France* and *Italy* tends only to fill *Great Britain* with dabblers in Virtù, pretenders in Taſte, ſcioliſts in Literature, and infidels in Religion.

But I perceive myſelf inſenſibly falling into what I mean to avoid — A diſcuſſion of the excellencies and defects of our Syſtem of Education. —

Our Excellencies are greater, perhaps, than thoſe who know us not are apt to ſuppoſe; and our defects are not ſo much defects in our Inſtitution (though I have never ſcrupled to profeſs an humble Opinion that it might be amended) as in our Diſcipline; and the defects in our diſcipline, are not ſo properly our defects, as the defects of the Manners of the Age. If a young Man at ſeventeen be accuſtomed at home to have horſes always at his command; to follow country diverſions without reſtraint; to mix in long convivial familiarity with perſons of advanced age; to drink as much as he pleaſes at his father's table; to hear improper connexions with the Sex ſpoken of in all companies as venial levities, and not to hear them ſeriouſly cenſured in any as Offences againſt Chriſtian Morality; and if to all this he be ſupplied, through a deſtructive indulgence, with ſums of money exceſſive for his age, and far ſuperior to his wants, can it be a matter of wonder, that it is not in the power of an Univerſity to rectify the diſorders of ſuch a domeſtic Education? I have no intention to miſlead the Opinion of the world concerning us, nor to exculpate ourſelves by criminating others. If we yield to the corruption of the Age, we yield as ſlowly as we can; and it is not, perhaps, poſſible for us, wholly to eſcape the Malignity of its Influence.

Cambridge,
Feb. 9, 1786.

PREFACE.

Three of the following tracts have been publiſhed, the other three were only printed and given away: they would make a fifth volume, but I think it would not be acceptable to many readers.

Inſtitutionum Chemicarum in Prælectionibus Academicis explicatarum, pars Metallurgica. Cantabrigiæ, 1768.

Experiments and Obſervations on various Phenomena attending the Solution of Salts. Publiſhed in the Philoſophical Tranſ. 1770.

An Eſſay on the Subjects of Chemiſtry and their general Diviſion. Printed at Camb. 1771.

A Plan of a Courſe of Chemical Lectures. Printed at Camb. 1771.

Some Remarks on the Effects of the great Cold in February, 1771. Publiſhed in the Phil. Tranſ. 1771.

Account of an Experiment made with a Thermometer, the Bulb of which was painted black, and expoſed to the direct Rays of the Sun. Publiſhed in the Phil. Tranſ. 1773.

ESSAY

ESSAY I.

Of Lapis Calaminaris—Blende—Zinc—Braſs.

THE two principal ores of zinc are *calamine* and *blende.* The Arabic word *climia*, or, as it is pronounced by ſome, *calimia*, denotes the ſame ſubſtance which we call *lapis calaminaris*, *calamine*, or *calamy*; and hence *Salmaſius* is of opinion, that they judge very prepoſterouſly who would derive *calamine* from *calaem*, an

Indian word ſignifying, according to him, a ſpecies of metal reſembling tin, which is dug near *Malacca* *. With due deference to his authority, I would obſerve, that Indian *calaem* is not like tin. Many years ago the Dutch took a Portugueſe veſſel which was laden with *calaem* †, and from all the experiments which were made upon that ſubſtance, it appeared to be *zinc*, or that metallic ſubſtance, which we in Europe have very lately

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[*] Cadmia Arabibus dicitur climia, quod quidam pronuntiarunt calimia, unde Græcis recentioribus κελιμια interdum ſcribitur, unde noſtris Gallis calamina et lapis calaminaris: quam vocem quidam præpoſtere deducunt ab Indico calaem, quod metalli genus eſt ſtanno ſimile haud longe ex Malacca erui ſolitum. Salm. de Homony. Hy. Iat. C. CXXII.

[†] Savotus de Num. Ant. P. II. C. XIV.

lately learned the method of extracting from calamine. Both *calamine* and *zinc* have the property of changing copper to a *yellow* colour; and this is the moſt diſtinguiſhing property of them both; it is that for which they are both ſought after in commerce, and as climia and calaem have the ſame radical letters, and denote in the Arabic and Indian languages, two ſubſtances which agree in one of their moſt characteriſtic properties, I leave it to others to determine whether they are not the ſame word, and in which of the two languages that word was originally formed. — The other ore of zinc is called by the Germans *blende*; from its blinding, or miſleading appearance; it looking like an ore of lead, but yielding (as was formerly thought) no metallic ſubſtance of any kind *. A particular ſort of lead ore has been called by *Pliny*, *galena*, from a Greek word ſignifying to ſhine, becauſe it is compoſed of ſhining particles; our potters ore and the Derbyſhire lead ore is of this ſort; blende much reſembles galena, but yielding no lead, it has been called falſe or *pſeudo-galena*, or *mock-lead*; our Engliſh miners have called it *black jack*, and that is the name by which it is known to the makers of braſs. Black jack reſembles lead ore ſo much, that the miners ſometimes ſucceed in ſelling, to inexperienced ſmelters, black jack inſtead of lead ore; I have heard of the fraud being carried to ſo great an extent in Derbyſhire, that from a ton of ore there was not obtained above a few ounces of lead; though a ton of unadulterated lead ore yields in Derbyſhire, at an average, 14 or 15 hundred weight of lead.

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* Pſeudo-galena nomen ſuum exinde acquiſivit, quod faciem quaſi mineræ plumbeæ præ ſe ferat, ſed mentiatur, cum id revera non contineat, quod externo aſpectu pollicetur. Germanis appellatur *blende* a *blenden*, quia, cum falſo ſpeciem mineræ ſaturninæ præ ſe fert, exinde oculos faſcinet, vel iis imponat. Pott de Pſeudo-galena, p. 106.—They have in Staffordſhire a ſort of iron, which they call *blende-metal*, of which they make nails, hammers, &c. Plot's Staf.

Calamine is found in moſt parts of Europe; we have great plenty of it in *Somerſetſhire*, *Flintſhire*, *Derbyſhire*, and in many other parts of England. It is ſcarcely to be diſtinguiſhed by its appearance from ſome ſorts of limeſtone; for it has none of the metallic luſtre uſually appertaining to ores; it differs, however, by its weight from every ſort of ſtone, it being, bulk for bulk, near twice as heavy as either flint, or limeſtone. Before the reign of Elizabeth, this mineral was held in very little eſtimation in Great Britain; and even at ſo late a period as towards the end of the laſt century, it was commonly carried out of the kingdom as ballaſt, by the ſhips which traded to foreign parts, eſpecially to Holland *. Its uſe is now as perfectly underſtood in England, as in any part of the world; and as we have greater plenty of calamine, and that of a better ſort, than moſt other nations have, there is no fear of our loſing the advantages in this article

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* Eſſay on Metal: Words by Sir J. Pettus, —and Phil. Tranſ. for 1694.

ticle of trade, which we are now poſſeſſed of.

Great quantities of calamine have of late years been dug in Derbyſhire, on a ſpot called *Bonſale* Moor, in the neighbourhood of *Matlock*. A bed of iron ſtone, about four feet in thickneſs, lies over the calamine; and the calamine is much mixed not only with this iron ſtone, but with cawk, lead ore, and limeſtone. The calamine miners never wiſh to meet with lead ore; they ſay, that it eats up the calamine; and the lead miners in return never wiſh to meet with calamine in a rich vein of lead ore, ſince they are perſuaded that it injures the quality of the ore. It would be too much to infer from theſe obſervations of the miners, that one of theſe ſubſtances ariſes from the natural decompoſition of the other. Juxtapoſition of ſubſtances in the bowels of the earth is no certain proof of their being derived from each other; for no one will contend that *chert* is derived from the limeſtone in which it is bedded; or flint and pyrites from the chalk in which they are found; yet when a great variety of ſubſtances are found mixed together in the ſame little lump, the mind cannot help conjecturing, that a more improved ſtate of mineralogy will ſhew ſome connexion in their origin. I have often ſeen *calamine*, and *black jack*, and *lead ore* — and *cawk*, *black jack*, and *lead ore* bedded together in the ſame piece of ſpar.

The calamine annually raiſed in Derbyſhire, amounts to about fifteen hundred tons. Sixty years ago, (as I was informed by an intelligent dealer in calamine, whoſe father was one of the firſt who dug it in that county,) they did not raiſe forty tons in a year. The *Derbyſhire* calamine does not bear ſo good a price as that which is gotten about Mendip in *Somerſetſhire*; the former being ſold for about forty ſhillings, and the latter for ſixty five or ſeventy ſhillings a ton before *dreſſing*: when thoroughly dreſſed, the Derbyſhire calamine may be bought for about ſix guineas, and the other for eight pounds a ton. This dreſſing of the calamine conſiſts, principally, in picking out all the pieces of lead ore, limeſtone, iron ſtone, cawk, and other heterogeneous ſubſtances which are mixed with it, when it is firſt dug from the mine; this picked calamine is then calcined in proper furnaces, and by calcination it loſes between a third and a fourth part of its weight.

The ſubſtance which is loſt during the calcination of the calamine is not either ſulphur or arſenic, or any thing which can be collected by the ſides of an horizontal chimney, as is the caſe in ſome ſorts of copper and lead ores; hence it would be quite unſerviceable to roaſt calamine in a furnace with ſuch a chimney. The truth of this remark will appear from the following experiment.

I took 120 grains of the beſt *Derbyſhire* calamine, and diſſolved them in a diluted vitriolic acid; the ſolution was made in a Florence flaſk, and the weight of the acid and flaſk was taken before the ſolution commenced.

About twenty hours after the ſolution had been finiſhed, I weighed the flaſk and its contents, and found that there had been a loſs of 40 grains, or one third the weight of the calamine; about a grain of earth remained at the bottom undiſſolved. If the ſame quantity of the pureſt limeſtone had been diſſolved in the ſame way, there would have been a loſs of weight equal to 54 grains; the ſubſtance which is ſeparated from calamine by calcination, or by ſolution in an acid, is of the ſame nature with that which is ſeparable from limeſtone by the ſame proceſſes—*fixed air*. This air having the property of changing the blue colour of vegetables to a red, as well as many other properties of an acid, and being contained in great abundance in the atmoſphere, has been called by ſome — *aerial acid* — and by others from its conſtituting nine parts in twenty of chalk and other calcareous earths — *chalky acid* — and from its being deſtructive of flame and animal life, ſome have denominated it — *mephitic air.* The weight which was thus loſt by diſſolving the Derbyſhire calamine in an acid, correſponds ſufficiently with that which the workmen obſerve to be loſt during the calcination of that mineral; ſo that theſe proceſſes, as was obſerved in a former Eſſay concerning ſimilar ones when applied to calcareous earths, mutually confirm each other.

Bergman obſerves, that 100 grains of *Flintſhire* calamine loſt by calcination 34 grains*; now this quantity correſponds, as much as can be expected,

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* Vol. II. p. 327.

pected, in things of this ſort, with the loſs which I obſerved during the ſolution of 120 grains of the *Derbyſhire* calamine; for if I had diſſolved only 100 grains, the loſs would have been $33\frac{1}{3}$. The ſame author, however, remarks that 100 grains of Flintſhire calamine, when diſſolved in an acid, gave only 28 grains of air; and he thinks that 6 grains of water are contained in every 100 grains of that ſort of calamine; for he takes the difference which he obſerved, between the weight of air obtained by ſolution, and the loſs of weight ſuſtained during the calcination of 100 grains of calamine, to be owing to the water which is diſperſed during the proceſs of calcination [*]. *Fontana* obtained 190 grains of fixed air from 576 grains of *So-merſetſhire* calamine; according to the ſame proportion, had he uſed only

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[*] Bergman has uſed the ſame method of analyz-

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analyzing other ſubſtances, containing fixed air, particularly calcareous earths. He found that 100 grains of tranſparent calcareous ſpar gave, by ſolution in an acid, 34 grains of fixed air, and loſt by calcination 45 grains; the difference, 11 grains, he ſays is water, which, though expelled by the fire, remains mixed with the acid, and hence 100 grains of ſuch ſpar contain 55 grains of lime, 34 grains of fixed air, and 11 grains of water. I have a little difficulty in admitting this mode of *inferring* the quantity of water contained in theſe bodies; I do not abſolutely deny the juſtice of it, but I heſitate concerning it; becauſe from experiments which I made with all the care I could, and which are mentioned in the Eſſay on calcareous earths, I found that fine tranſparent ſpar, very white marble, &c. loſt, as nearly as could be eſtimated, the ſame weight, whether they were diſſolved in an acid, or calcined in a ſtrong fire.

100 grains, he would have had 33 grains of fixed air, inſtead of the 28 which Bergman got from the Flintſhire calamine; I ſay inſtead of the 28, for I am inclined to think, that the Derbyſhire, Flintſhire, and Somerſetſhire calamines do not differ much from each other in the quantity of air which they contain; but that the apparent difference, in the analyſes of them here mentioned, proceeds rather from the mode of operating, than from the ſubſtances themſelves. But though future experience ſhould prove, that very pure pieces of the calamines we are ſpeaking of do exactly agree, as to the quantity of air contained in them, it will not follow, that the calamines, as prepared for ſale by the miners or burners, will be ſimilar to each other in all

their properties; ſince they may be mixed with different quantities and with different ſorts of heterogeneous ſubſtances; from which it may be impoſſible wholly to free them.

The reader muſt not conclude, from what has been ſaid, that all ſorts of calamine loſe one third of their weight by calcination, or afford fixed air by ſolution in acids. Bergman analized ſome calamine from Hungary, and he found 100 grains of it to conſiſt of 84 grains of the earth of zinc, 3 of the earth of iron, 1 of clay, and 12 of ſilicious earth; no mention is made of water in this analyſis *.

In the great works, where calamine is prepared for the braſs-makers, after it has been properly calcined, by which

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* Berg. Chem. Eſſ. Vol. II. p. 325.

which proceſs, as has been obſerved, it loſes between a third and a fourth part of its weight, it is again carefully picked, the heterogeneons parts having been rendered more diſcernible by the action of the fire; it is then ground to a fine powder, afterwards it is waſhed in a gentle rill of water, in order to free it, as much as poſſible, from the earthy particles with which it may be mixed; for theſe, being twice as light as the particles of the calamine, are carried off from it by the water; it is then made up for ſale. A ton of the crude Derbyſhire calamine, as dug from the mine, is reduced, by the various proceſſes it undergoes before it becomes ſaleable, to about twelve hundred weight; and hence it has loſt 8 parts in 20. Of the 8 hundred weight thus loſt in a ton, $6\frac{2}{3}$ may be eſteemed fixed air, the remaining part, amounting to $1\frac{1}{3}$, conſiſts of ſome impurities which have been picked out or waſhed away, and of ſome portion of the metallic part of the calamine, which is inflamed and driven off during the calcination; for I cannot agree with *Wallerius* * in ſuppoſing that the ores of zinc loſe no part of their ſubſtance during the ordinary proceſs of calcination; the blue flame which is viſible in the furnace where the calamine is calcined, and the injury which the calamine ſuſtains from being calcined with too ſtrong a fire, are proofs to the contrary. It would be poſſible to uſe calamine for the purpoſe of making braſs without calcining it, for the fixed air would be diſſipated by the heat applied in making the braſs. But as in uſing a ton of uncalcined calamine, there would be between ſix and ſeven hundred weight put into the braſs pots, which would be of no manner of uſe in the operation, it is a wiſer method to get rid of ſo large a quantity of unſerviceable matter; eſpecially as the carriage of ſix or ſeven hundred weight to the diſtance to which the prepared calamine is ſent for the making of braſs, would coſt more than the calcination of a ton of it amounts to.

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* Metallur.

There are many ſorts of *blende* or *black jack*, which differ from each other not only in their external appearance, but in their internal conſtitution. In general they contain zinc and ſulphur, united together by the intervention of iron, or of calcareous earth: and they muſt be previouſly freed from their ſulphur by calcination, before they can be applied to the making of braſs. Some ſorts of black jack loſe one fourth, other about one ſixth of their weight by calcination; what is thus diſperſed conſiſts principally of ſulphur with a little water; what remains conſiſts of a large portion of zinc earth, mixed with one or more of the following ſubſtances, viz. iron, lead, copper, clay and flint. Black jack is found in *North Wales*, in *Cornwall*, and in *Derbyſhire*; and probably it may be met with in many other parts of Great Britain. It has for many years been uſed, as well as calamine, for the making of braſs at Briſtol, and, I believe, it was firſt uſed there under a patent; but ſo little was this application of it known in other parts of the kingdom, that in the year 1777, they begged me in Derbyſhire (where they had a little before that time begun to ſave it) not to divulge the purpoſe to which it might be applied.

It has not been long well underſtood, that either calamine or black jack contained any metallic ſubſtance. *Matthiolus*, *Agricola*, *Caneparius*, and other expert and more ancient metallurgiſts, eſteemed calamine to be a mineral, in which there was no metallic ſubſtance *. Their miſtake on this ſubject was very excuſeable; for the metallic ſubſtance contained in calamine, being of a volatile and combuſtible nature, it is conſumed or diſſipated by the ordinary proceſſes in which metals are extracted from their ores. Moſt ores require to be fluxed in contact with charcoal, or ſome other ſubſtance containing phlogiſton, before they will yield their metals; and when they are thus fluxed, the metal, inſtead of being diſperſed in vapour, is collected into a maſs at the bottom of the veſſel, or furnace, in which the operation is performed. Calamine, in like manner, muſt be united to phlogiſton, before its metallic part, which is called zinc, will be properly formed; but as ſoon as it is formed, it flies off in vapour, and taking fire burns with a vivid flame. This phenomenon is eaſily made apparent, by mixing calamine in powder and charcoal duſt together, and expoſing the mixture to a melting heat, for a flame will iſſue from it very different from what charcoal alone would yield; no maſs of any metallic ſubſtance will be found at the bottom of the veſſel; but in the place where the experiment is made, there will be ſeen many white flocks floating in the air; theſe flocks are the aſhes of the metallic ſubſtance of the calamine, they are called *flowers of zinc*, *lana philoſophorum*, *nihil album*, and by other fanciful names. The metallic vapour which riſes from a mixture of calamine and charcoal, when expoſed to a proper degree of heat, and the firing of which cauſes the flame which may be obſerved, cannot burn without air; and it was on this principle that Marggraf proceeded, when he extracted zinc from calamine by diſtillation in cloſe veſſels in 1746. He put 8 parts of powdered calamine, and 1 of powdered charcoal well mixed together, into an earthen retort; and having fitted a receiver, with a little water in it, to the neck of the retort, in ſuch a manner as to exclude the air, he expoſed the mixture to a ſtrong heat; there roſe into the neck of the retort, where it was condenſed, the metallic vapour of the calamine. By this method he aſcertained the quantity of zinc contained in different ſorts of calamine.

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* Canep. de Atram. p. 12—21.

	Parts.		Parts.	
Calamine from near Cracow	16	gave	2½	of zinc.
——— from England	16	—	3	———
——— from Breſlaw	16	—	4½	———
——— from Hungary	16	—	2⅓	———
——— from Holywell in Flintſhire	16	—	7	———

He tried ſome ſtones from *Aix-la-Chapelle*, which had been given him for calamine, in the ſame way, but obtained no zinc from them, and thence he concludes, that they were not calamine ſtones; for every ſtone, ſays he, which being mixed with charcoal, and expoſed in cloſe veſſels to the action of a violent fire, does not yield zinc; or which in an open fire does not with copper and charcoal produce braſs, ought not to be conſidered as a calamine ſtone*: Henckel had long before given a ſimilar definition of zinc, when he obſerved that it was the only ſubſtance in nature which had the quality of giving copper a yellow colour †.

Pott wrote a diſſertation on zinc in 1741, in which he enters into the hiſtory of the diſcovery of this ſemi-metal; *Bergman* has availed himſelf of all that Pott knew on the ſubject, and has added ſeveral things of his own; I cannot compreſs the matter into a leſs compaſs than he has done. "The ſemi-metal, which at preſent is called zinc, was not known ſo much as by name to the ancient Greeks and Arabians. The name which it bears at preſent firſt occurs in Theophraſtus Paracelſus*, but no one as yet has been able to diſcover the origin of this appellation. A. G. Agricola calls it contrefeyn †; Boyle, ſpeltrum ‡: by others it is denominated ſpiauter, and Indian tin ‖. Albertus Magnus, more properly called Bolſtadt, who died in 1280 *, is the firſt who makes expreſs mention of this ſemi-metal. He calls it golden marcaſite, aſſerts that it approaches to a metallic nature, and relates that it is inflammable. However as zinc is white, the name of golden marcaſite is not very proper; it would therefore appear probable, that it derives that name from the golden colour which it communicates to copper, had not Albertus expreſsly ſaid, that copper united with golden marcaſite becomes white; but he has probably either miſunderſtood or miſrepreſented what he had heard related by others. It may alſo happen, that zinc was formerly thought to contain gold. J. Mattheſius † in 1562, mentioned a white and a red zinc;

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* Opuſ. de Marg Vol. II. p. 94.

† Pyrito. French Tranſ. p. 248,

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* In Operibus paſſim

† De Re metallica.

‡ Ponderab. flammæ.

‖ Tæda Trifida Chymica.

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* In Libro mineralium.   † Sarepta.

zinc; but the yellowneſs and redneſs are only to be underſtood of the ores. Hollandus, Baſil Valentine, Aldrovandus, Cæſius, Cæſalpinus, Fallopius and Schroeder, obſerve a profound ſilence on that head *. The eaſtern Indians have long ſince been in poſſeſſion of the method of extracting pure zinc from the ore; at leaſt in the courſe of the laſt century this metal was brought from thence to Europe. Jungius mentions the importation of zinc from India, in 1647 †; a metal of this kind, under the name of tutenag, is ſtill brought from thence, which muſt be carefully diſtinguiſhed from the compound metal of that name. G. E. Van Lohneiſs tells us, in 1617, that a long

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* Pott on Zinc.

† De Mineralibus.

long time before zinc had been collected by fuſion at Goſlar *. It has been long uſual to form orichalcum from the ores of zinc by the addition of copper; but it does not yet appear at what time this art was invented. Pliny makes mention of the orichalcum, as alſo of three ſpecies of Corinthian vaſes, one of which is yellow, and of the nature of gold †. Eraſmus Ebner, of Noremberg, in the year 1550, was the firſt who uſed the cadmia of Goſlar for this purpoſe. In the year 1721, Henckel indeed mentioned that zinc might be obtained from lapis calaminaris by means of phlogiſton, but he conceals the method ‡. The celebrated Anton,

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* Bericht Von Bergvercken.

† Hiſt. Nat. XXX. C. II.

‡ Pyritologia — Henckel's words deſerve to

ton. Van Swab, in 1742, extracted it from the ores by diſtillation, at Weſterwick in Dalecarlia *. It was determined to found a work for the purpoſe of extracting larger quantities of this ſemi-metal: but afterwards, for various reaſons, this pro-

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to be quoted, I take them from the French tranſlation of the Pyritologia, p. 295. — On fait, par exemple, avec la calamine, non-ſeulement du fer, il eſt vrai en petite quantité, mais encore *une tres grande quantite de zinc*, que l'on obtient non-ſeulement en lui préſentant le corps avec lequel il peut s' incorporer, c'eſt-a-dire le cuivre qui eſt ſon aiman, mais encore ce demi-metal ſe montre ſimplement par l' addition d' une *matiere graſſe qui metalliſe*; il faut ſeulement pour eviter que ce phénix ne ſe reduiſe en cendre, *empécher qu' il ne ſe brûle*, et obſerver le tems et les circonſtances.

* Elogium magni hujus Metallurgi coram R. Acad. Stock. recitatum.

ject was laid aſide; therefore the illuſtrious Marggraf, not knowing what had been done by the Swediſh mineralogiſts, in the year 1746, publiſhed a method of performing this operation, which he had diſcovered himſelf *. It is not known how zinc is extracted in China. A certain Engliſhman, who ſeveral years ago took a voyage to that country for the purpoſe of learning the art, returned ſafely home, indeed, and appears to have been ſufficiently inſtructed in the ſecret, but he carefully concealed it. We find afterwards that a manufactory had been eſtabliſhed at Briſtol, where zinc is ſaid to be obtained by diſtillation per deſcenſum. We have already ſeen that it had been before obtained in Sweden

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* Mem. de l'Acad. de Berlin.

Sweden by diſtillation per aſcenſum, which afterwards was effected in larger quantity by Meſſ. Cronſtedt and Riman, two very celebrated mineralogiſts and metallurgiſts. The difficulties occaſioned by the volatile and combuſtible nature of this metal for a long time retarded the knowledge of the ores containing it; nor is that wonderful, as being of a metallic form, it has even to our times been conſidered as compoſed of two or three ingredients. Albertus Magnus thinks iron an ingredient; Paracelſus called it a ſpurious ſon of copper; Lemery holds it to be a ſpecies of biſmuth; Glauber, and many alchemiſts, conſider it merely as an immature ſolar ſulphur; Homberg, as a mixture of tin and iron; Kunckel, as a coagulated mercury;

Schluter, as tin made brittle by ſulphur, &c.—The celebrated Brandt, in 1735, ſhewed that blende contained zinc *; and ſoon after D. Swab actually extracted it from the Bolognian Pſeudo-galena, which poſſeſſes a metallic ſplendor. The Baron Funch, in 1744, determined the preſence of zinc in pſeudo-galena from the flame and the flowers †; and in 1746, Mr. Marggraf ſet the matter out of doubt."

Bergman in this hiſtory of the diſcovery of the method of extracting zinc from calamine, wholly omits the mention of *Dr. Iſaac Lawſon*; of whom Pott, in his Eſſay on Zinc, ſpeaks very reſpectfully, acquainting us that he really obtained ſome grains of that ſemi-metal from calamine.

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* Act. Upſal.

† Act. Stock.

mine. So that though *Henckel* was the *firſt*, *Lawſon* was, probably, the *ſecond* perſon in Europe who procured zinc from calamine; whether he was the Engliſhman who, according to Bergman, went to China to diſcover the method of doing it, is what I have not been able to learn with certainty. Our Engliſh writers, who have touched on this ſubject, ſpeak in high terms of Lawſon, I ſuppoſe from their perſonal knowledge of him, for they do not refer to any written account[*]. Thus Dr. Pryce ſays, "* the late Dr. I. Lawſon obſerving that the flowers of lapis calaminaris were the ſame as thoſe of zinc, and that its effects on copper were alſo the ſame with that ſemimetal, never remitted his endeavours till he found the method of ſeparating pure zinc from that ore." And Dr. Campbell, in his Survey of Britain, is ſtill more particular: "† the credit if not the value of calamine is very much raiſed ſince an ingenious countryman of ours diſcovered that it was the true mine of zinc; this countryman was Dr. I. Lawſon, who died before he had made any advantage

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[*] Pott gives us ſeveral quotations from a diſſertation of Dr. Lawſon's De Nihil, which I have never met with, and amongſt others the following one, Quamvis lapis calaminaris nec ſublimatione, nec cum fluxu nigro det zincum, tamen ſimiles flores, ſimilis in igne color, ſimilis tinctura cupri, et augmentum

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mentum ponderis probabiliſſimum præbent argumentum lapidem calaminarem eſſe mineram zinci. Pott De Zinco, p. 9.

[*] Mineral. Cornub. p. 46.

[†] Polit. Surv. of Brit. Vol. II. p. 35.

tage of his diſcovery." The authors of the Supplement to Chambers' Dictionary, publiſhed in 1753, expreſsly affirm, that "* Dr. Lawſon was the firſt perſon who ſhewed that calamine contained zinc; we have now on foot at home a work eſtabliſhed by the diſcoverer of this ore, which will probably make it very unneceſſary to bring any zinc into England."—To all this I ſhall only add one teſtimony more, from which it may appear that the Engliſh knew how to extract zinc from calamine, before Mr. Van Swab taught the Swedes the method of doing it; though this gentleman, unleſs I have been miſinformed, inſtructed the late Mr. *Champion* of Briſtol, either in the uſe of black jack for the ſame pur-

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* Artic. Calam. & Zinc.

poſe as calamine, or taught him ſome improvements in the method of obtaining zinc from its ores. The teſtimony occurs in a diſſertation of Henckel's on zinc, publiſhed in 1737, he is there ſpeaking of the great hopes which ſome perſons had entertained of the poſſibility of obtaining zinc from calamine; hopes, he ſays, which had been realized in England, Ce qu' un Anglois arrivé depuis peu de Briſtol, dit avoir vu réuſſir dans ſon pays*.

The manufactory, however, of zinc was not eſtabliſhed at Briſtol till about the year 1743, when Mr. *Champion* ob-

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* This obſervation was firſt publiſhed in the 4th vol. of the Acta Phyſico-Medica Acad. Nat. Cur. 1737, but I have made the quotation from the Ed. of Henckel's Works, publiſhed at Paris, 1760, Vol. II. p. 494.

obtained a patent for the making of it. About 200 tons of zinc are annually made at the place where the manufactory was firſt ſet up; and about ſeven years ago, zinc began to be made at Henham near Briſtol, by *James Emerſon*, who had been many years manager of that branch under Mr. Champion, and his ſucceſſor in the buſineſs.

Near twenty years ago I ſaw the operation of procuring zinc from calamine performed at Mr. Champion's copper works near Briſtol; it was then a great ſecret, and though it be now better known, yet I am not certain whether there are any works of the kind yet eſtabliſhed in any other part of either England or Europe, except that before mentioned at *Henham*. In a circular kind of oven, like a glaſs houſe furnace, there were placed ſix pots of about four feet each in height, much reſembling large oil jars in ſhape; into the bottom of each pot was inſerted an iron tube, which paſſed through the floor of the furnace into a veſſel of water. The pots were filled with a mixture of calamine and charcoal, and the mouth of each was then cloſe ſtopped with clay. The fire being properly applied, the metallic vapour of the calamine iſſued through the iron tube, there being no other place through which it could eſcape, and the air being excluded, it did not take fire, but was condenſed in ſmall particles in the water, and being remelted was formed into ingots, and ſent to Birmingham under the name of zinc or ſpelter *. The reader will underſtand that this zinc will be more or leſs pure, according as the calamine is free from or mixed with iron, lead, copper, or other metallic ſubſtances. At *Goſlar* in *Germany* they ſmelt an ore which contains lead, and ſilver, and copper, and iron, and zinc in the ſame maſs; the ore is ſmelted for the purpoſe of procuring the lead and ſilver, and by a particular contrivance in the furnace, which is well deſcribed by Cramer †, they obtain a portion of zinc in ſubſtance; another portion of it is inflamed, and the aſhes of the zinc which is thus conſumed, and which it has been obſerved before are called philoſophic wool, &c. ſtick to the top and ſides of the furnace, and are denominated by the ſmelters *cadmia fornacum*, or *furnace fragment:* theſe aſhes are uſed as calamine is for the making of braſs. We know nothing of the method of fluxing the zinc which is brought from India. According to Muſſchenbroeck, a cubic foot of Indian zinc weighs 7240 ounces; the ſame bulk of Goſlar zinc, taking the medium of three ſpecimens, gave 7210 ounces *; the Goſlar zinc, which I examined, gave only 6953 ounces to a cubic foot; a cubic foot of Engliſh zinc, from Briſtol, weighs 7028, and hence if the lightneſs of zinc be a criterion of its purity, our Engliſh zinc is preferable to the Indian and nearly equal to the German zinc.

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* There is another ſubſtance which is denominated ſpelter or ſpelter ſolder by the braziers, it is compoſed of two parts of zinc and of one of braſs.

† Ars Docim. Vol. I. p. 236.

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* Introd. ad Phil. Nat. Vol. II.

If the reader has never ſeen a piece of zinc, it will give him ſome idea of it to be told, that in colour it is not unlike lead; that it is hard and ſonorous, and malleable in a ſmall degree; that it does not melt ſo eaſily as either tin or lead, but more eaſily than ſilver or copper; that in a degree of heat juſt ſufficient to melt it, it burns away into a kind of gray aſhes without being inflamed; that in a ſtronger heat it burns with a yellowiſh blue or green flame, reſolving itſelf into a white earth, which is either driven off by the violence of the fire during the combuſtion, or remains ſurrounding the burning zinc like a piece of cotton wool. This combuſtion of zinc is as ſtriking an experiment as any in chemiſtry, and it is in the power of any perſon to make it, by ſprinkling filings of zinc on a pan of burning charcoal, or on a poker or other piece of iron heated to a white heat: it is this property which renders fine filings of zinc of great uſe in fire-works. Zinc is a very ſingular metallic ſubſtance, it not only burns when ſufficiently heated with a vivid flame, but it yields an inflammable air by ſolution in the acids of vitriol and of ſea ſalt, and even in ſome of its ores it manifeſts a phoſphoric quality; I have ſeen a piece of black jack from Freiberg, which being ſcratched in the dark with the nail of a finger emitted a ſtrong white light. The Chineſe zinc is ſaid to contain about half a pound of lead in an hundred, and the German zinc ſomewhat more *, and our Engliſh zinc is thought by ſome to make the copper with which it is melted harſher and leſs malleable, than when either of the other ſorts of zinc is uſed; though this opinion I ſuſpect is rather founded in prejudice than in truth. There is an eaſy method, when pure zinc is required, of obtaining it: nothing more is requiſite than to melt it with ſulphur and ſome fat ſubſtance to prevents its calcination, for the ſulphur will unite itſelf to the lead, the copper, or the iron contained in the zinc, and reduce them to a kind of ſcoria which may be ſeparated from the melted zinc, but it

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* Berg. Eſſ. Vol. II. p. 318, note.

it has no action on the zinc itſelf*. The zinc made by Mr. Emerſon is whiter and brighter than any other either Engliſh or foreign zinc, but I do not know that it owes theſe qualities to its being purified by ſulphur. Zinc and copper, when melted together in different proportions, conſtitute what are called pinchbecks, &c. of different yellow colours. Marggraf melted pure zinc and pure copper together, in a great variety of proportions, and he found that eleven, or even twelve parts of copper being mixed with one part of zinc, (by putting the zinc into the copper when melted) gave a moſt beautiful and very malleable tombac or pinchbeck [*]. Mr. Baumé gives the following proceſs for making a metal, which he ſays is called *Or de Manheim*, and which is uſed for imitating gold in a variety of toys, and alſo on lace. — Melt an ounce and an half of copper, add to it three drams of zinc, cover inſtantly the mixture with charcoal duſt to prevent the calcination of the zinc [†]; this covering of the melted maſs with charcoal is certainly ſerviceable in the way the author mentions; and it is on a ſimilar principle, that when they melt ſteel at Sheffield they keep the ſurface of it covered with charcoal; but I think it probable alſo, that the charcoal contributes to exalt the golden colour of the pinchbeck. Theſe yellow metals are ſeldom ſo malleable as braſs, on account of the zinc which is uſed in making them not being in ſo pure a ſtate, as that is which is combined with copper when braſs is made; yet it appears from the experiments of Marggraf and Baumé before mentioned, that when pure zinc and pure copper are uſed in proper proportions, very malleable braſs may be made thereby. Mr. Emerſon has a patent for making braſs with zinc and copper, as I have been informed, and his braſs is ſaid to be more malleable, more beautiful, and of a colour more reſembling gold than ordinary braſs is. It is quite free from knots or hard places, ariſing from iron, to which other braſs is ſubject, and this quality, as it reſpects the magnetic needle, renders it of great importance in making compaſſes: the method of making ordinary braſs I will now deſcribe.

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* I am aware that Mr. Morveau has found out a method of combining zinc with ſulphur; but in this general view, I purpoſely paſs over many things which are deſervedly eſteemed of great importance by perſons deeply ſkilled in chemiſtry.

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[*] Mem. of Berlin, 1774.

[†] Chy. par M. Baumé, Vol. II. p. 662.

Copper in thin plates, or, which is better, copper reduced (by being poured, when melted, into water) into grains of the ſize of large ſhot is mixed with calamine and charcoal, both in powder, and expoſed in a melting pot for ſeveral hours to a fire not quite ſtrong enough to melt the copper, but ſufficient for uniting the metallic earth of the calamine to the phlogiſton of the coal; this union forms a metallic ſubſtance, which penetrates the copper contiguous to it, changing its colour from red to yellow, and augmenting its weight in a great proportion. The greater the ſurface of a definite weight of copper, the more ſpace has the metallic vapour of the calamine to attach itſelf to, and this is the reaſon that the copper is granulated, and that it is kept from melting and running into a maſs at the bottom of the veſſel, till near the end of the operation, when the heat is increaſed for that purpoſe.

The German braſs-makers, in the time of *Erckern*, uſed to mix 64 pounds of ſmall pieces of copper with 46 pounds of calamine and charcoal, and from this mixture they generally obtained 90 pounds of braſs*. Cramer recommends 3 parts of powdered calamine to be mixed with an equal weight of charcoal duſt and 2 parts of copper, and ſays, that the braſs ob-

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* Fleta Minor. by Sir J. Pettus, p. 286. Newman gives the ſame proportions, p. 65.

obtained by the proceſs exceeds the weight of the copper by a fourth, or even a third part of its weight *. At moſt of our Engliſh braſs-works they uſe 45 pounds of copper to 60 pounds of calamine for making ingot braſs, and they ſeldom obtain leſs than 60 or more than 70 pounds of braſs; at Holywell they reckon the medium product to be 68: and hence a ton of copper, by this operation, becomes rather more than a ton and an half of braſs. This is a larger increaſe of weight in the copper, than is obſerved in any of the foreign manufactories that I have ever read of, and it may be attributed to two cauſes, to the ſuperior excellence of our calamine, and to our uſing *granulated* copper. Poſtlethwayte,

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* Cram. Ars Doc. Vol. II. p. 246.

thwayte, in his Commercial Dictionary, attributes the difference in the increaſe of weight acquired by the braſs to the different natures of the coppers which are uſed, "there is an increaſe of 48 or 50 pounds in an hundred, if copper of Hungary or Sweden be uſed; that of Norway yields but 38, and that of Italy but 20." When they make braſs which is to be caſt into plates, from which pans and kettles are to be made, and wire is to be drawn, they uſe calamine of the fineſt ſort, and in a greater proportion than when common braſs is made, generally 56 pounds of calamine to 34 of copper. Old braſs which has been frequently expoſed to the action of fire, when mixed with the copper and calamine in the making of braſs, renders the braſs far more ductile and fitter for the making of fine wire than it would be without it; but the German braſs, particularly that made at *Nuremberg*, is, when drawn into wire, ſaid to be preferable to any made in England for muſical inſtruments. If this preference be real, it will ceaſe to exiſt as ſoon as any ingenious man ſhall undertake to examine the ſubject, for our materials for making braſs are as good as any in the world. The quantity of charcoal which is uſed, is not the ſame at all works, it is generally about a fourth part of the weight of the calamine; an exceſs of charcoal can be attended with no other inconvenience than that of uſeleſsly filling up the pots in which the braſs is made; but powdered pitcoal, which is uſed at ſome works in conjunction with, or in the place of charcoal, greatly injures the malleability of the braſs. As to black jack, the other ore of zinc, it is not ſo commonly uſed as calamine for the making of braſs. The manufacturers have been ſomewhat capricious in their ſentiments concerning it, ſome have preferred it to calamine, and others have wholly neglected it; and the ſame perſons at different times have made great uſe of it, or intirely laid it aſide. There muſt have been ſome uncertainty in the produce or goodneſs of braſs made by this mineral, to have occaſioned ſuch different opinions concerning it, and this uncertainty may have proceeded either from the variable qualities of the mineral itſelf, or from the unſkilfulneſs of the operators in calcining, &c. a mineral to which they had not been much accuſtomed. Several ſhip loads of it were ſent a few years ago from Cornwall to Briſtol, at the price of 40 ſhillings down to a moidore a ton*. Upon the whole, however, experience has not brought it into reputation at Briſtol.

For many purpoſes braſs is more uſeful than copper: it is lighter, harder, more ſonorous, more fuſible, leſs liable to ſcale in the fire, and to ruſt in the air. It is not malleable when hot, and in this reſpect it is inferior to copper; but when cold it may be beat out into thin leaves, as may be ſeen in the braſs leaf which emulates in colour and thinneſs gold leaf. If a braſs leaf be held in the flame of a candle, the metallic part of the calamine will be inflamed, and the braſs will be changed into copper. This change of braſs into copper will take place in the largeſt maſſes as well as in thin leaves of it, if the braſs be kept a ſufficient time in a ſtate of fuſion. The varieties in the colour, malleability, and ductility of braſs, proceed from the quantity and quality of the calamine imbibed by the copper; and the quality of the copper itſelf is a circumſtance of no ſmall importance in the making of braſs. "I have obſerved, ſays Dr. Lewis *, in a large ſet of experiments on this ſubject, that a little of the calamine (that is, of the zinc contained in the calamine) dilutes the colour of the copper and renders it pale; that when the copper has imbibed about one twelfth of its own weight,

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* Miner. Cornu. p. 47.

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* Newman's Chem. by Lewis, notes, p. 65.

weight, the colour inclines to yellow; that the yellowneſs increaſes more and more till the proportion comes almoſt to one half; that on further augmenting the calamine, the braſs becomes paler and paler, and at laſt white." As to the different qualities of different kinds of copper, they are ſufficiently known to workmen employed in fabricating it; and philoſophers have ſo far obſerved them as to diſtinguiſh the different ſorts of copper by the different weights which appertain to equal bulks of them. The lighteſt copper which Muſſchenbroeck has noticed, is that which is precipitated from the copper waters in *Hungary*; a cubic foot of this ſort weighed, when melted, 7242 ounces; and the heavieſt ſort he mentions is the *Japan* copper, a cubic foot of it, when ſimply melted, weighing 8726 ounces. The difference of the weights of equal bulks of theſe two ſorts of copper is very conſiderable; but yet it is much leſs than what may be obſerved between two ſpecimens of the ſame ſort of copper, one of which has been *caſt*, and the other has been *wrought:* the ſame Hungarian copper, which, when barely melted, weighed 7242 ounces to the cubic foot, when it had been condenſed by being long hammered, weighed 9020. Many of our Engliſh writers eſtimate the weight of a cubic foot of copper at 9000 ounces *, but they do not ſay, whether the copper was melted merely, or hammered; nor from what mine it was procured. I found the weight of a cubic foot of plate-braſs from Briſtol to be 8441 ounces; and that of a cubic foot of old braſs from the bottom of an old kettle to be 8819, which ſhews that it approached to the weight of copper, and indeed from the redneſs of its appearance it ſeemed as if all the zinc had been burned away. I had a preſent made me of a fine *celt*, (the antiquaries are not agreed concerning the uſes to which the celts were applied, nor whether they are to be eſteemed Britiſh or Roman inſtruments) it was covered over with a thick *patina*; I heated it in the fire, in order to get rid of this precious patina, or green ruſt, and took the ſpecific gravity of it when quite freed from its ruſt with great care; a cubic foot of it would have weighed only 6290 ounces. It was not malleable either when hot or cold: I then melted it, when in a ſtate of fuſion it emitted a blue flame, and a thick white ſmoke, which are eſteemed certain marks of zinc; I melted it a ſecond time, but there was no appearance of either flame or ſmoke, the zinc having been all conſumed; I could not obſerve any lead in it; a cubic foot of it, after it was gently cooled from its ſtate of fuſion, weighed 8490 ounces, and it was now malleable as cold braſs always is; it was compoſed, I think, of copper, calamine, and tin; and I have heard that ſome celts contain a little ſilver. The change of texture which it had undergone, by being long buried in the earth, occaſioned its comparative levity; this diminution of weight, which decaying braſs ſuſtains, is not peculiar to braſs, it probably belongs to iron, and other metallic ſubſtances ſubject to decay, and it certainly belongs to many ſpecies of ſtones. I have in another place obſerved, that a cubic foot of *toadſtone* has different weights, according as the ſtone is more or leſs decayed; that which is moſt decayed being the lighteſt. We have a ſtratum of bluiſh gray *ragſtone* in *Weſtmoreland*, which lies under the limeſtone; large cobbles of this ſort of ſtone, which are expoſed to the air, are decayed to a certain depth from the ſurface, whilſt the inward part ſeems intire; a cubic foot of the outward part of one of theſe ſtones weighed 2378, when the inward part of the ſame ſtone weighed 2603 ounces to the cubic foot. This ragſtone is very hard, but the ſame phenomenon may be noticed in a ſtone ſtill harder. The *Cambridgeſhire* black flint weighs 2592 ounces to the cubic foot; the ſame flint being in *part* decayed and become *externally* white, though black within, weighed 2414, and when become *wholly* white, 2400 ounces to the cubic foot: the general reaſon of this ſeems to be, that the pores of the decayed body are augmented. Mr. Kirwan has well explained the manner in which nature operates in decompoſing ſtones. " Flints, jaſpers, petro-ſilex, feltſpar, granites, lavas and ferrugineous ſtones, have frequently been ſaid to be decompoſed by the air, and the obſervations of Mr. Greville and Sir W. Hamilton have removed every doubt I entertained on this head. With regard to ferrugineous ſtones, in which the calx of iron is not much de-

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* Cotes, Ferguſon, Martin, Campbell.

dephlogiſticated, this decompoſition is eaſily underſtood, for this calx gradually becomes more dephlogiſticated by the action of water and air, attracts water and fixed air, and loſes its adherence with the ſiliceous, or other ſtony particles: this is ſeen to happen to baſaltes, toadſtone, ferrugineous limeſtone, &c. In other ſtones this decompoſition may ariſe from their containing calcareous earth in a cauſtic ſtate, or mangaueſe, for theſe will gradually attract water and fixed air, and then ſwell, burſt and looſen the whole texture of the ſtone, as we ſee happen to bricks that contain lime. Thus alſo glaſs is decompoſed by long expoſure to the air, the alkali attracting water and aerial acid. Mortar on the contrary hardens by long expoſure to the air, becauſe, though the aerial acid be attracted, yet a great part of the water exhales*." The changes produced by the long expoſure of bodies to the air, and the cauſes of them, deſerve a more minute inveſtigation than has hitherto been beſtowed on them; ſome advantage might, perhaps, be derived from the inquiry to our manufacturers, for I have cauſe to think that iron, which has been expoſed to the air for three or four years, is a very different ſubſtance from the ſame iron when juſt made: and the ſame obſervation will probably hold with reſpect to copper and braſs.—But to return from this digreſſion.

The calamine of *Bohemia* contains iron; moſt of our Engliſh calamine contains lead; and there are ſome ſorts which contain both iron and lead, and other metals in different proportions: theſe ſorts can ſeldom be freed from the extraneous metals, and hence, in the ordinary method of making braſs, they will be mixed with it, being fuſible in the degree of heat uſually employed in making braſs. *Cramer* mentions a very ingenious method of making braſs, by which, if it ſhould be thought neceſſary to do it, the braſs may be preſerved pure from theſe heterogeneous mixtures. He orders the calamine and charcoal to be mixed with moiſtened clay, and rammed to the bottom of the melting pot, and the copper mixed with charcoal to be placed upon the clay; then, the proper degree of heat being applied, the vapour of the zinc contained in the calamine will aſcend through the clay, and attach itſelf to the copper, but the iron, or lead contained in the calamine, not being volatile, will remain in the clay, and the braſs when the whole is melted will not be mixed with them, but reſt pure on the ſurface of the clay. Mr. *John Champion*, brother to him who firſt eſtabliſhed the manufactory of zinc at Briſtol, is a very ingenious metallurgiſt, and he has lately obtained a patent for making braſs by combining zinc in vapour with heated copper plates, and the braſs is ſaid to be very fine; whether the proceſs he uſes has any correſpondence with this mentioned by Cramer, or not, his braſs will certainly be free from the mixture of lead, &c. But the care to purify braſs from ſuch metallic mixtures as may be accidentally contained in the calamine, is, or is not neceſſary, according to the purpoſes to which braſs is applied. Theſe mixtures may probably injure the malleability of the braſs, but they may at the ſame time increaſe its hardneſs, or render it ſuſceptible of a better poliſh, or give it a particularity of colour, or ſome other quality by which it may be more uſeful in certain manufactories, than if it was quite free from them, and conſiſted of nothing but of the pureſt metallic part of the calamine, united to the pureſt copper. This may be illuſtrated from what is obſervable in other metals. The red iron ore from *Furneſs* in *Lancaſhire* produces an iron, which is as tough as *Spaniſh* iron, it makes very fine wire; but when converted into bars, it is not eſteemed ſo good as that which is made in the foreſt of *Dean*, and other places. There are but few ſorts of iron which, though uſeful in other reſpects, are fit for being converted into ſteel: ſome ſorts of iron will admit an high poliſh, as may be ſeen in many expenſive grates which are ſold as grates of poliſhed ſteel, though they are nothing but iron, whilſt others take but a very indifferent poliſh; the *Swediſh*, *Ruſſian*, and *Engliſh* irons, and even the irons made at different furnaces in the ſame country are reſpectively fit for ſome purpoſes, and unfit for other; he who ſhould attempt to uſe the ſame iron for the making of wire, and for coach and waggon wheels, would betray great ignorance in his buſineſs.

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* Elements of Min. by R. Kirwan, p. 111.

In like manner, a notable difference may be obſerved in different ſorts of copper, yet all of them have their reſpective uſes: the Swediſh copper is more malleable than the copper of Hungary; the copper of Angleſey differs from the copper of Cornwall and of Staffordſhire. The braziers prefer that copper which they can work with the greateſt facility, but the malleability of copper ſhould not be eſteemed the only criterion of its goodneſs; for the copper which is leſs malleable may admit a finer poliſh, and may laſt longer when expoſed, as in breweries, in the navy, &c. to the action of the fire, than the copper which is more malleable. This has been proved by experiment. Three plates of copper, equal to each other in ſurface and thickneſs, were ex-

expoſed, for the ſame length of time, to a violent fire, with a view of ſeeing which would beſt ſuſtain its action; one plate was made of copper which had been purified by a chemical proceſs, another was made of copper from Hungary, and the third of Swediſh copper. The purified copper, when freed from the calcined ſcales, had loſt 5 grains of its weight, that of Hungary had loſt 8, and that of Sweden 11 grains*.

Queen Elizabeth, in 1565, granted by patent all the calamine in England and within the Engliſh Pale in Ireland to her aſſay maſter *William Humphrey*, and one *Chriſtopher Shutz* a German, and, as the patent ſets forth, a workman of great cunning, knowledge and experience, as well in the finding of calamine, as in the proper uſe of it for the compoſition of the mixt metal called *latten* or *braſs* *. With theſe patentees were ſoon after aſſociated ſome of the greateſt men in the kingdom, as Sir Nicholas Bacon, the Duke of Norfolk, the Earls of Pembroke and Leiceſter, Lord Cobham, Sir William Cecil, and others, and the whole were incorporated into a ſociety, called, The Society for the Mineral and Battery Works in the year 1568. Mines of *latten*, whatever may have been at that period meant by the word, are mentioned in the time of Henry VI. who made his chaplain John Bottwright, comptroller of all his mines of gold and ſilver, copper, latten, lead, within the counties of Devon and Cornwall *; yet I am diſpoſed to think, that the beginning of the braſs manufactory in England may be properly referred to the policy of Elizabeth, who invited into the kingdom various perſons from Germany, who were well ſkilled in metallurgy and mining. In 1639, a proclamation was iſſued prohibiting the importation of braſs wire †; and about the year 1650, one *Demetrius*, a German, ſet up a braſs work in Surry, at the expence of ſix thouſand pounds ‡; and above eight thouſand

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* Mem. de Brux. Vol. IV.

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* Opera Mineralia explicata, p. 34. This work was written by Moſes Stringer, M. D. in 1713, and contains a complete hiſtory of the ancient corporation of the city of London, of and for the *mines*, the *mineral* and *battery works*.

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* Id. p. 20. † Id. p. 147.

‡ Eſſays on Metal Words — Braſs.

men are ſaid to have been employed in the braſs manufactories, which were eſtabliſhed in Nottinghamſhire, and near London, yet Sir John Pettus, in his account of royal mines, publiſhed in 1670, obſerves that theſe braſs works were then decayed, and the art of making braſs almoſt gone with the artiſts *. But though the art was then *almoſt* gone, yet it was never, after its firſt eſtabliſhment, altogether loſt; for about the year 1708, we find that there were braſs manufacturers in England, and that they preſented a memorial to the Houſe of Commons, ſetting forth ſeveral reaſons for continuing the braſs manufactory in this kingdom, and ſoliciting for it the protection of parliament †. In this memorial they ſtated that England, by reaſon of the inexhauſtible plenty of calamine, might become the ſtaple of braſs manufactory for itſelf and foreign parts; that the continuing the braſs works in England would occaſion plenty of rough copper to be brought in, and make it the ſtaple (in time) of copper and braſs; that the Swedes had endeavoured to ſubvert the Engliſh braſs manufactory, by lowering the price of Swediſh braſs wire, inveigling away workmen, and other means. In compliance with the purport of this memorial, an act of parliament was paſſed in the ſame year, by which the former duties payable on the exportation of copper of the produce of Great Britain, and of *braſs wire*, were taken off, and theſe articles were allowed to be exported free of duty.

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* Fodinæ Regal. p. 33.

† Oper. Min. exp. p. 156.

In 1720 it was remarked, that this nation could ſupply itſelf with copper and braſs of its own produce ſufficient for all occaſions, if ſuch duties were laid on foreign copper and braſs, as would diſcourage their importation, and at the ſame time encourage the ſale of our own metals *. At preſent the braſs manufactory is eſtabliſhed amongſt us in a very great extent; we are ſo far from being obliged to have recourſe to any of our neighbours for this commodity, that we annually export large quantities of manufactured braſs to Flanders (it was formerly called Flanders metal) France, Germany,

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* State of the Copper and Braſs Manufactures, by W. Wood. — The ſame perſon whom Swift handled ſo roughly in his Drapier's Letters.

many, Portugal, Spain, Ruſſia, Africa, and moſt other parts of the world. In 1783, a bill was paſſed by the Houſe of Commons for repealing certain ſtatutes prohibiting the exportation of braſs. In the reign of Edward III. the exportation of iron, either made at home or brought into England, had been prohibited upon the pain of forfeiting double the value of the quantity exported *. And in the reigns of Henry VIII. and Edward VI. ſeveral acts of parliament had been paſſed, prohibiting the exportation of braſs, copper, latten, bell-metal, pan-metal, gun-metal, ſhrof-metal, under the ſame penalty †. The general reaſon for paſſing

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* 28 Ed. III. c. 5.

† 21 Hen. VIII. c. 10.—33 Hen. VIII. c. 7.—2 & 3 Ed. VI. c. 37.

paſſing theſe acts certainly does not apply to the preſent ſtate of our mines and manufactures, for the reaſon was this,—leſt there ſhould not be metal enough left in the kingdom fit for making of guns and other engines of war, nor for houſhold utenſils. The forementioned acts of parliament were partially repealed, by an act paſſed in the ſixth year of William and Mary, by which it was rendered lawful to export, after the 25th of March, 1694, all manner of iron, copper, or mundick metal; but the prohibition of the other metals was continued. The braſs-makers in 1783 applied for the ſame liberty, which had been granted to the iron and copper ſmelters, a liberty of exporting the crude commodity; this liberty was not granted them by the legiſlature, for the bill which had paſſed the Houſe of Commons, was thrown out by the Lords. The *Birmingham* manufacturers preſented a petition to the houſe of commons againſt the bill which was then pending; in which petition it was repreſented — that frequent attempts had been made to erect manufactures ſimilar to thoſe of Birmingham in different parts of Europe, and that the excellence of ſome of the Birmingham articles depended upon braſs of very different qualities, and that, fortunately for this country, there were ſeveral ſorts of braſs that were peculiarly adapted to the different branches of their manufactures; ſo that the ſort which was ſuitable for one article, was improper for another: and that they had reaſon to believe, that the manner of adapting the various ſorts of Engliſh braſs to different articles in their manufactures, was not known to foreigners; but that if free liberty was given to export braſs, every maker might be induced to diſcover the peculiar uſes of his ſort, and that very diſagreeable conſequences to their manufactures might thereby be produced. The petitioners alſo repreſented — that braſs-makers, in different provinces of this kingdom, had not ſucceeded in making the ſorts of braſs made in other provinces; and that one great company of braſs-makers had not ſucceeded in making braſs ſuitable for the Birmingham market, though they had profeſſed an earneſt deſire to do ſo. And they humbly apprehended, that there never had been ſuch a quantity of braſs exported as to render it a national object, and that there was not a probability of any ſuch quantity being exported, though ſo much might be as to raiſe a ruinous competition to their manufactures, &c.

The braſs-makers, it may be ſaid, ſuffer an injury in being prohibited from exporting a commodity by which they might be gainers, merely leſt the great braſs manufacturers ſhould loſe ſomewhat of their profit, by having a leſs extenſive trade. But this is not a proper ſtate of the caſe; it is not for the ſake of the great braſs manufacturers that the prohibition of exporting braſs is continued, nor is there any want of that metal in the kingdom; but leſt foreigners ſhould rival us in a trade which, in affording employment to many thouſands of people, is of the greateſt conſequence to the kingdom in general. The proprietors of *Fuller's Earth* have been prohibited from exporting that material, not out of any partial regard of the legiſlature for the great woollen manufacturers, but leſt the number of perſons employed in that manufacture ſhould be much leſſened, if foreigners were ſupplied with an article ſo eſſentially neceſſary to its perfection, as fuller's earth is found to be; and though other nations have fuller's earth, yet that which is met with in England is reckoned to be fitter for the woollen manufactory, than any other which has yet been found in any part of the world. This obſervation may be applied to the ſubject we are ſpeaking of. Great quantities of good braſs are made by moſt nations in Europe, as well as by the Engliſh; but the Engliſh braſs is more adapted to the Birmingham manufactories, than any other ſort is; and hence in *France*, *Portugal*, *Ruſſia*, and *Germany*, our *unmanufactured* braſs is allowed to be imported *free of duty*, but heavy duties are impoſed in thoſe countries on manufactured braſs when imported. The manner of mixing different ſorts of braſs, ſo as to make the mixture fit for particular manufactures, is not known to foreigners; though this is a circumſtance of the greateſt importance; but there can be little doubt that if foreign nations were poſſeſſed of all the ſorts of Engliſh braſs, they would ſoon ſeduce our workmen to inſtruct them in the manner of mixing them, and in ſome other little circumſtances, which are not generally known, but on which the ſucceſs of the manufacture depends in a great degree. On theſe and other accounts, till commerce puts on a more liberal appearance than it has hitherto done in Europe, till different nations ſhall be diſpoſed to conſider themſelves, with reſpect to commercial intereſt, as different provinces only of the ſame kingdom, it may, probably, be thought expedient to continue the acts prohibiting the exportation of unwrought braſs, though the reaſons which induced the legiſlature to paſs them have long ſince ceaſed to exiſt. I do not enter into the inquiry, when the cuſtom houſe officers began to make a diſtinction between *wrought* and *unwrought* braſs, ſo as to admit the former to an entry for exportation, and not the latter; but I apprehend it was in the year 1721, when various goods and merchandizes of the product or manufactures of Great Britain were allowed, by act of parliament, to be exported free of duty: *lapis calaminaris*, lead, and ſeveral other articles are enumerated in the act, on which the duty was to be continued; but in this enumeration there is no mention made of *unwrought* braſs, though it may properly be conſidered as a merchandize of the product of Great Britain; but the quantity of braſs which was then made in the kingdom was ſo ſmall, that it did not, probably, enter into the contemplation of the legiſlature to forbid an exportation, which did not ſeem likely ever to take place. Braſs is made in various parts of Great Britain; but the *Briſtol*, *Macclesfield*, and *Warrington* companies are the only ones, I believe, which go through all the proceſſes of ſmelting the copper from its ore, of preparing the calamine, and of uniting it with copper for the making of braſs. The trade of braſs-making has within theſe few months been much deranged throughout the nation, by an agreement which has been entered into by ſome of the principal copper companies, to the excluſion of others, to buy up all the copper of the mines now at work in the kingdom. The effect of this plan is not yet generally either felt or foreſeen.

The following Eſſay was written ſeveral years ago; it is now printed, with little alteration, from a copy which I tranſmitted in 1783 to *The Literary and Philoſophical Society at Mancheſter*, as a ſmall Tribute of Gratitude for the unſolicited and unexpected honour they had done me, in electing me one of their members.

ESSAY II.

On Orichalcum.

WE have a proof, from the writings of *Cicero*, that the *Romans*, in his time, underſtood by the term *Orichalcum*, a metallic ſubſtance reſembling gold in colour, but very inferior to it in value. He puts the following caſe — " Whether, if a perſon ſhould offer a piece of *gold* to ſale, thinking that he was only diſpoſing of a piece of *orichalcum*, an honeſt man ought to inform him that it was really gold, or might fairly buy for a penny what was worth a thouſand times as much [*]." It is not contended, that the argument, in this place, required any great accuracy in aſcertaining the relative values of gold and orichalcum; yet we may reaſonably conclude from it, that orichalcum might by an ignorant perſon be miſtaken for gold, and, that it was but of ſmall eſtimation when compared with it.

Julius Cæſar robbed the capitol of three thouſand pound weight of gold, and ſubſtituted as much gilded copper in its ſtead [†]; in this ſpecies of ſacrilege, he was followed by *Vitellius*, who deſpoiled the temples of their gifts and ornaments, replacing the gold and ſilver by tin and orichalcum *. From this circumſtance alſo, we may collect, that the Roman orichalcum reſembled gold in colour, though it was far inferior to it in value.

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[*] Cicer. de Off. L. III.

[†] Suet. in Jul. Cæſ. C. LIV.

It is probable, that the orichalcum here ſpoken of, was a metallic ſubſtance greatly analogous to our braſs, if not wholly the ſame with it. The value of our braſs is much leſs than that of gold, and the reſemblance of braſs to gold in colour, is obvious at firſt ſight. Both braſs and gold, indeed, are ſuſceptible of a variety of ſhades of yellow; and, if very pale braſs be compared with gold mixed with much copper, ſuch as the foreign goldſmiths, eſpecially, uſe in their toys, a dif-

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* Id. in Vitel. C. VI.

diſparity may be ſeen; but the nearneſs of the reſemblance is ſufficiently aſcertained in general, from obſerving that ſubſtances gilded with braſs, or, as it is commonly called, Dutch leaf, are not eaſily diſtinguiſhed from ſuch as are gilded with gold leaf.

The *Romans* were not only in poſſeſſion of a metallic ſubſtance, called by them orichalcum, and reſembling gold in colour, but they knew alſo the manner of making it; and the materials from which they made it, were the very ſame from which we make braſs. I am ſenſible, that in advancing this opinion, I diſſent from authors of great credit, who eſteem the art of making braſs to be wholly a modern invention. Thus M. *Cronſtedt* (though I differ in opinion from him) " does not think it juſt to conclude from old coins and other antiquities, that it is evidently proved, that the making of braſs was known in the moſt ancient times[*];" the authors of the French *Encyclopedie* aſſure us, that "our braſs is a very recent invention[†];" and Dr. Laughton[‡] ſays, "the veſſels here called brazen, after ancient authors, cannot have been of the materials our preſent braſs is compoſed of, the art of making it is a modern diſcovery."

Pliny, ſpeaking of ſome copper which had been diſcovered near *Corduba* in the province of *Andaluſia* in *Spain*, ſays, "this of all the kinds of copper, the *Livian* excepted, abſorbs moſt *cadmia*, and imitates the goodneſs of *aurichalcum* *." The expreſſion, 'abſorbs moſt *cadmia*,' ſeems to indicate, that the copper was increaſed in bulk, or in weight, or in both, by means of the *cadmia*. Now it is well known, that any definite quantity of copper is greatly increaſed, both in bulk and in weight, when it is made into braſs by being fluxed in conjunction with *calamine*. The other attribute of the copper when mixed with *cadmia*, was, its reſembling *aurichalcum*. We have ſeen from *Cicero*, that the term *orichalcum* was applied to a ſubſtance far leſs valuable than gold, but ſimilar to it in colour; and it is likely enough, that the *Romans* commonly called the mixture of copper and *cadmia* orichalcum, though *Pliny* ſays, that it only reſembled it; he, as a naturaliſt, ſpeaking with preciſion, and diſtinguiſhing the real orichalcum, which in his time, he ſays, was no where produced, from the factitious one, which, from its reſemblance to it, had uſurped its name.

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[*] Miner. p. 218.

[†] Art. Orichalque.

[‡] Laughton's Hiſt. of Ancient Egypt, p. 58.

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* Hiſt. Nat. L. XXXIV. S. II.

Sextus Pompeius Feſtus abridged a work of *Verrius Flaccus*, a grammarian of conſiderable note in the time of *Auguſtus*. In this abridgement, he defines *cadmia*, to be an earth which is thrown upon copper, in order to change it into orichalcum*. The age in which *Feſtus* flouriſhed is not aſcertained: he was unqueſtionably poſterior to *Martial*, and ſome have thought that he lived under the Chriſtian Emperors. But leaving that point to be ſettled by the critics, if he expreſſed himſelf in the words of the author, whoſe work he abridged, we have from him a deciſive proof, that *cadmia* was conſidered as a ſpecies of earth, and that the Romans uſed it for the converting of copper into a metallic ſubſtance called, in the Auguſtan age, orichalcum.

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* Cadmia-Terra quæ in æs conjicitur, ut fiat orichalcum. Feſ. de Ver. Seq.

In oppoſition to this, it ought to be remarked, that ſome underſtand by the *cadmia* of *Pliny*, not calamine, but native arſenic. They ſeem to have been led into this opinion, from obſerving that Pliny ſays, *lapis ærosus* was called *cadmia*. For, apprehending that by *lapis ærosus*, Pliny underſtood a kind of ſtone which cauſed ulcers and eroſions in the fleſh of thoſe who were occupied in working it, and knowing that arſenic produced ſuch an effect, they have concluded that cadmia was native arſenic *. This, probably, is a miſtake, ariſing from a miſinterpretation of the word, *æroſus*. Pliny uſually, if not conſtantly, applies that word to ſubſtances in which copper is contained, without having any reſpect to the actions of ſuch ſubſtances on the fleſh of animals. Arſenic, moreover, when mixed with copper, does not give a gold, but a ſilver like appearance to copper. And laſtly, Pliny † in another place expreſsly ſays, that the ſtone from which braſs (*æs*) was made, was called cadmia; now it is impoſſible to make either braſs or copper from arſenic.

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* - - - - nous ſoupçonnons que Pline a voulu deſigner par lapis æroſus, une pierre qui mange et fait des ulceres ou éroſions a ceux qui la travaillent, et qui eſt probablement l'arſenic vierge. Miner. par M. Valmont de Bomare, V. II. p. 64.—If the word had been *eroſus*, this criticiſm might have been admitted.

† Hiſt. Nat. L. XXXIV. 10.

Ambroſe, biſhop of *Milan* in the fourth century, ſays, that copper, mixed with certain drugs, was kept fluxed in the furnace till it acquired the colour of gold, and that it was then called aurichalcum [*]. *Primaſius*, biſhop of *Adrumetum* in *Africa*, in the ſixth century, obſerves, that aurichalcum was made from copper, brought to a golden colour by a long continued heat, and the admixture of a drug [†]. *Iſidorus*, biſhop of *Seville* in *Spain*, in the ſeventh century, deſcribes aurichalcum as poſſeſſing the ſplendour of gold, and the hardneſs of copper, and he uſes the very words of Primaſius reſpecting the manner of its being made *. The drug ſpoken of by theſe three biſhops was probably *cadmia*. Prepared *cadmia* is highly commended by Pliny as uſeful in diſorders of the eyes †, and it is ſtill with us, under the more common appellation of *calamine*, in ſome repute for the ſame purpoſe. Hence, conſidering the teſtimonies of *Feſtus*

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[*] Æs namque in fornace, quibuſdam medicaminibus admixtis, tamdiu conflatur, uſque dum colorem auri accipiat, et dicitur aurichalcum. Amb. in Apoc. C. I.

[†] Aurichalcum ex ære fit, cum igne multo; et

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et medicamine adhibito, perducitur ad aureum colorem. Prima. in Apoc. C. I.

* Aurichalcum dictum, quod et ſplendorem auri, et duritiam æris poſſideat, fit autem ex ære et igne multo, ac medicaminibus perducitur ad aureum colorem. Iſid. Orig.

† Hiſt. Nat. L. XXXIV. C. X.

Feſtus and *Pliny* to the application of *cadmia* in making either orichalcum, or a ſubſtance imitating the goodneſs of orichalcum, we cannot have much doubt in ſuppoſing, that *cadmia* was the drug alluded to by *Ambroſe*, and by thoſe who ſeem to have borrowed, with ſome inaccuracy of expreſſion, his deſcription of the manner of making orichalcum.

What we call braſs, was anciently in the French language called *archal*, and braſs wire is ſtill not unfrequently denominated *fil d' archal*. Now if we can infer, from the analogy of languages, that *archal* is a corruption of *aurichalcum*, we may reaſonably conjecture, that our braſs, which is the ſame with the French *archal*, is the ſame alſo with the Roman *aurichalcum*.

Though we may, from what has been advanced, conclude, without much apprehenſion of error, *that the Romans knew the method of making braſs, by melting together calamine and copper*; yet the invention was probably derived to them from ſome other country.

We meet with two paſſages, one in *Ariſtotle*, the other in *Strabo*, from which we may collect, that braſs was made in *Aſia*, much after the ſame manner, in which it appears to have been made at Rome.

Strabo informs us, that in the environs of *Andêra*, a city of *Phrygia*, a wonderful kind of ſtone was met with, which being calcined became iron, and being then fluxed with a certain earth, dropped out a ſilver-looking metal, which, being mixed with copper, formed a compoſition, which ſome called orichalcum [*]. It is not improbable, I think, that this ſtone reſembled *black jack*, or ſome other ore of zinc. Black jack may, in a common way of ſpeaking, be called a ſtone. It abounds in iron; and, when calcined, looks like an iron earth: it yields zinc by diſtillation, ſometimes mixed with ſilver and lead; and both the metallic ſubſtance which may be extracted from black jack, and the ſublimate which ariſes from it, whilſt it is ſmelted, will, when mixed with copper, make braſs.

The *Moſſynæci* inhabited a country not far from the *Euxine* Sea, and their copper, according to *Ariſtotle*, was ſaid to have become ſplendid and white, not from the addition of tin, but from its being mixed and *cemented* with an *earth* found in that country *. This cementing of copper with an earth, is what is done, when braſs is made, by uniting copper with calamine, which is often called, and, indeed, has the external appearance of, an *earth:* and that *Aſia* was celebrated for its cadmia or calamine, we have the teſtimony of Pliny †. The copper of the Moſſynæci is ſaid to have become *white* by this operation. Whiteneſs appertains to braſs, either abſolutely, or relatively: for braſs is not only much whiter than copper; but when it is made with a certain quantity of a particular ſort of calamine, for there are very various ſorts of it, its ordinary yellow colour is changed into a white. Cicero, we have ſeen ſuppoſes that orichalcum might have been miſtaken for gold, and as ſuch, it muſt have been yellow; yet Virgil applies the epithet white to orichalcum,

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[*] Strab. Geo. L. XIII.

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* Ariſ. de Mirab. Op. Tom. II. p. 721.

† Hiſt. Nat. L. XXXIV. C. II.

Ipſe dehinc auro ſqualentem *alboque* orichalco
Circumdat loricam humeris *.

Ariſtotle alſo ſpeaks of having heard of an *Indian* copper, which was ſhining, and pure, and free from ruſt, and not diſtinguiſhable in colour from gold †; and he informs us, that amongſt the veſſels of *Darius* there were ſome, of which, but for the peculiarity of their *ſmell*, it would have been impoſſible to ſay, whether they were made of gold or copper. This account ſeems very deſcriptive of common braſs, which may be made to reſemble gold perfectly in colour, but which, upon being handled, always emits a ſtrong and peculiar *ſmell*, not obſervable either in gold or gilded copper.

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* Virg. Æn. L. XII. 87.

† Ariſ. de Mirab. T. II. p. 719.

The kings of *Perſia*, who preceded the *Darius* mentioned by *Ariſtotle*, were in poſſeſſion of ſimilar veſſels; but they ſeem to have been rare, and of courſe were held in high eſtimation. Among the magnificent preſents of gold and ſilver veſſels, which *Artaxerxes* and his counſellors gave to *Ezra*, for the ſervice of the temple at *Jeruſalem*, there were twenty baſons of gold, and but two veſſels of *yellow* ſhining copper, precious as gold, or, as ſome render the words, reſembling gold*. "Sir John Chardin,

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* Ezra viii. 27.

din, in his MS. note, has mentioned a mixt metal uſed in the eaſt, and highly eſteemed there; and, as the origin of this compoſition is unknown, it might, for aught we know, be as old as the time of *Ezra*, and be brought from thoſe more remote countries into *Perſia*, where theſe two baſons were given to be conveyed to Jeruſalem. 'I have heard,' ſays the note, 'ſome Dutch gentlemen ſpeak of a metal in the iſland of Sumatra, and among the Macaſſars, much more eſteemed than gold, which royal perſonages alone might wear. It is a mixture, if I remember right, of gold and ſteel, or of copper and ſteel.' He afterwards added to this note (for the colour of the ink differs) 'Calmbac is this metal compoſed of gold and copper. It in colour nearly reſembles the pale carnation roſe, has a very fine grain, the poliſh extremely lively. I have ſeen ſomething of it, &c. Gold is not of ſo lively and brilliant a colour; I believe, there is ſteel mixed with the gold and copper.' He ſeems to be in doubt about the compoſition; but very poſitive as to its beauty and high eſtimation *."

The ſuppoſition of braſs having been anciently made in *India*, ſeems to be rendered improbable by both *Pliny* and *Strabo*; Pliny expreſsly ſaying, that the Indians had no copper †, and without copper we are certain that braſs cannot be made; and Strabo repreſenting them as ſo ignorant of the art of fluxing metals ‡, that, according to him, if they had been poſſeſſed of the materials, they would not have had the ability to uſe them for the compoſing of braſs. But theſe writers, it is apprehended, knew very little of India. Strabo, in particular, laments his want of materials to compoſe a conſiſtent account of India; and few of the authors, from whoſe works Pliny compiled his natural hiſtory, can be ſuppoſed to have had any intercourſe with that country. Strabo, moreover, contradicts both Pliny's obſervation, and his own. In deſcribing the great pomp with which ſome of the Indians were accuſtomed to celebrate their feſtivals, he ſpeaks of huge gilt kettles, cups, and tables made of *Indian* copper *; from which it appears.

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* Harmer's Obſ. on Scrip. Vol. II. p. 491.

† Hiſt. Nat. L. XXXIV. C. XVII.

‡ Geo. L. XIV.

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* Id. LXXVI.

pears, not only that the Indians were not deſtitute of copper, but that they were ſkilful metallurgiſts, ſince they knew how to flux it, to form it into veſſels of various kinds, and to gild it. Perhaps, this Indian copper, of which the veſſels were made, inſtead of being gilt, only reſembled gold in colour, and was really a ſort of braſs. It is granted that this is but a conjecture, but it is not devoid of probability; for, not to mention that the author, whoever he was, from whom Strabo extracted this account, might, in a public exhibition, have eaſily miſtaken poliſhed braſs for gilt copper, nor the little probability, that cauldrons, and kettles, and ſuch veſſels as were in conſtant uſe, would be gilded in any country, we have reaſon to believe, from what has been obſerved before, that a peculiar kind of veſſels, probably reſembling ſome of thoſe exhibited in the Indian feſtivals, had been long in uſe in *Perſia*, and that they were made of Indian copper without any gilding. We know that there is found in India, not only copper ſtrictly ſo called, but zinc alſo, which being mixed with copper conſtitutes braſs, pinchbeck, tombac, ſimilor, and all the other metallic mixtures which reſemble gold in colour. On the whole, it appears probable to me, *that braſs was made in the moſt remote ages in India, and in other parts of Aſia, of copper and calamine*, as it is at preſent.—If the *celt* be allowed to be a *Britiſh* inſtrument, then may we be certain, from what was obſerved concerning it in the laſt Eſſay, that our anceſtors knew the method of mixing together calamine and copper; for though tin and copper when melted together, in certain proportions, will give a bluiſh green flame, yet that flame is not accompanied with a thick white ſmoke, and there are but few proportions in which any flame at all is to be ſeen.

With reſpect to orichalcum, it is generally ſuppoſed that there were two ſorts of it, one factitious, the other natural; the factitious, whether we conſider its qualities or compoſition, appears to have been the ſame with our braſs. As to the natural orichalcum, there is no impoſſibility in ſuppoſing, that copper ore may be ſo intimately blended with an ore of zinc, or of ſome other metallic ſubſtance, that the compound, when ſmelted, may yield a mixt metal of a paler hue than copper, and reſembling the colour of either gold or ſilver. In *Du Halde's* hiſtory of *China*, we meet with the following account of the Chineſe *white copper*. " The moſt extraordinary copper is called *Pe-tong*, or white copper: it is white when dug out of the mine, and ſtill more white within than without. It appears, by a vaſt number of experiments made at *Peking*, that its colour is owing to no mixture; on the contrary all mixtures diminiſh its beauty; for, when it is rightly managed, it looks exactly like ſilver, and were there not a neceſſity of mixing a little *tutenag*, or ſome ſuch metal with it, to ſoften it, and prevent its brittleneſs, it would be ſo much the more extraordinary, as this ſort of copper is, perhaps, to be met with no where but in China, and that only in the province of *Yunnan* *." Notwithſtanding what is here ſaid, of the colour of this copper being owing to no mixture, it is certain, that the Chineſe white copper, as brought to us, is a mixt metal; ſo that the ore, from which it is extracted, muſt conſiſt of various metallic ſubſtances, and from ſome ſuch ore it is poſſible that the natural orichalcum, if ever it exiſted, may have been made. But, though the exiſtence of natural orichalcum cannot be ſhewn to be impoſſible, yet there is ſome reaſon to doubt, whether it ever had a real exiſtence or not: for I pay not much attention to what father Kircher has ſaid of orichalcum being found between *Mexico* and the ſtraits of *Darien*, becauſe no other author has confirmed his account, at leaſt none on whoſe ſkill in mineralogy we may rely *.

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* Phil. Tranſ. Vol. I. p. 16.

We know of no country in which it is found at preſent; nor was it any where found in the age of *Pliny*; nor does he ſeem to have known the country where it ever had been found. He admits, indeed, its having been formerly dug out of the earth; but it is remarkable, that in the very paſſage, where he is mentioning by name the countries moſt celebrated for the production of different kinds of copper, he only ſays, in general, concerning orichalcum, that it had been found in other countries, without ſpecifying any particular country. *Plato* acknowledges, that orichalcum was a thing only talked of even in his time; it was no where then to be met with, though in the iſland of *Atlantis* it had been formerly extracted from its mine. The *Greeks* were in poſſeſſion of a metallic ſubſtance, called orichalcum, before the foundation of *Rome*; for it is mentioned by *Homer*, and by *Heſiod*, and by both of them in ſuch a manner as ſhews, that it was then held in great eſteem. Other ancient writers have expreſſed themſelves in ſimilar terms of commendation; and it is principally from the circumſtance of the high reputed value of orichalcum, that authors are induced to ſuppoſe the ancient orichalcum to have been a natural ſubſtance, and very different from the factitious one in uſe at Rome, and, probably, in Aſia, and which, it has been ſhewn, was nothing different from our braſs.

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* Kirch. Mund. Sub.

But this circumſtance, when properly conſidered, does not appear to be of weight ſufficient to eſtabliſh the point. Whenever the method of making braſs was firſt found out, it is certain that it muſt have been for ſome time, perhaps for ſome ages, a very ſcarce commodity; and this ſcarcity, added to its real excellence as a metallic ſubſtance, muſt have rendered it very valuable, and intitled it to the greateſt encomiums. *Diodorus Siculus* ſpeaks of a people, who willingly bartered their gold for an equal weight of iron or copper *; and the Europeans have long carried on a ſimilar kind of commerce with various nations. Gold, in ſome views, is juſtly eſteemed the moſt valuable of metals; in other, and thoſe the moſt important to the well-being of human kind, it is far inferior to iron, or copper, or braſs. An individual, whoſe life depended upon the iſſue of a ſingle combat, to be decided by the ſword, would have no heſitation in preferring a ſword of ſteel, to one of gold; and an army, which ſhould be poſſeſſed of golden armour, would not ſcruple to exchange it, in the day of battle, for the iron accoutrements of their enemies. The preference of the harder metals to gold, is not leſs obvious in agriculture, than in war; a plough-ſhare, ſpade, mattock, chizel, hammer, ſaw, nail, of gold, is not for uſe ſo valuable, as an inſtrument of the ſame kind made of iron or braſs. Hence, there is no manner of abſurdity in ſuppoſing that orichalcum, when firſt introduced among the ancients, might have been prized at the greateſt rate, though it had been poſſeſſed of no other properties, than ſuch as appertain to braſs. When iron was either not at all known, or not common in the world, and copper inſtruments, civil and military, were almoſt the only ones in uſe *, a metallic mixture, reſembling gold in ſplendour, and preferable to copper, on account of its ſuperior hardneſs, and being leſs liable to ruſt, muſt have greatly excited the attention of mankind, been eagerly ſought after, and highly extolled by them. The *Romans*, no doubt, when it had been ſtipulated in the league which *Porſenna* made with them, after the expulſion of the *Tarquins*, that they ſhould not uſe iron, except in agriculture, muſt have eſteemed a metallic mixture ſuch as braſs, at a rate not eaſily to be credited *. It is not here attempted to prove, that there never was a metallic ſubſtance called orichalcum, ſuperior in value and different in quality from braſs; but merely to ſhew, that the common reaſon aſſigned for its exiſtence, is not ſo cogent as is generally ſuppoſed.

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* Lib. III.

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* Heſiod.

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* In fœdere quod, expulſis regibus, populo Romano dedit Porſenna, nominatim comprehenſum invenimus, ne ferro niſi in agricultura uterentur Plin. Hiſt. Nat. Vol. II. p. 666. Was Porſenna induced to prohibit the Romans the uſe of iron arms, from the opinion, which ſeems to have prevailed in Greece two hundred years afterward — that wounds, made with copper weapons, were more eaſily healed, than thoſe made with iron? Ariſ. Op. L. IV. p. 43.

Conſidering the few ancient writers we have remaining, whoſe particular buſineſs it was to ſpeak with preciſion concerning ſubjects of art, or of natural hiſtory, we ought not to be ſurprized at the uncertainty in which they have left us with reſpect to orichalcum. Men have been ever much the ſame in all ages; or, if any general ſuperiority in underſtanding is to be allowed, it may ſeem to be more properly aſcribed to thoſe who live in the manhood or old age of the world, than to thoſe who exiſted in its infancy or childhood: eſpecially as the means of acquiring and communicating knowledge are, with us, far more attainable than they were in the times of either Greece or Rome. The Compaſs enables us to extend our reſearches to every quarter of the globe with the greateſt eaſe *; and an hiſtorical narration of what is ſeen in diſtant countries, is now infinitely more diffuſed than it could have been, before the invention of printing; yet, even with theſe advantages, we are, in a great meaſure, ſtrangers to the natural hiſtory of the earth, and the civil hiſtory of the nations which inhabit it. He who imports *tutenag* from the Eaſt Indies, or *white copper* from *China* or *Japan*, is ſure of meeting with a ready market for his merchandize in *Europe*, without being aſked any queſtions concerning the manner how, or the place where, they are prepared in. An ingenious manufacturer of theſe metallic ſubſtances might wiſh, probably, to acquire ſome information about them, in order to attempt a domeſtic imitation of them; but the merchant who imports them, ſeems to be too little intereſted in the ſucceſs of his endeavours, to take much pains in procuring for him the requiſite information. Imitations, however, have been made of them, and we have an European *tutenag*, and an European *white copper* *, differing, in ſome qualities, from thoſe which are brought from Aſia, but reſembling them in ſo many other, that they have acquired their names. Something of this kind may have been the caſe with reſpect to orichalcum, and the moſt ancient Greeks may have known no more of the manner in which it was made, than we do of that in which the Chineſe prepare their white copper: they may have had too an imitation of the original, and their authors may have often miſtaken the one for the other, and thus have introduced an uncertainty and confuſion into their accounts of it.

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* Buffon quotes Homer's Odyſſey, and ſome Chineſe authors, to prove that the uſe of the mariner's compaſs in navigation was known to the ancients, at leaſt three thouſand years ago. Nat. Hiſt. by Buffon, Vol. IX. p. 17. Smellie's Tranſ,

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* The ingenious Dr. *Higgins* has been honoured by the Society for the Encouragement of Arts, &c. with a gold medal for *white copper* made with Engliſh materials, in imitation of that brought from the Eaſt Indies. His proceſs has not, I believe, been yet made public. Mem. of Agricul. Vol. III. p. 459.

There is as little agreement amongſt the learned concerning the etymology of orichalcum, as concerning its origin. Thoſe who write it *aurichalcum*, ſuppoſe that it is an hybridous word, compoſed of a Greek term ſignifying copper, and a Latin one ſignifying gold. The moſt general opinion is, that it ought to be written *orichalcum*, and that it is compounded of two Greek words, one ſignifying copper, and the other a mountain, and that we rightly render it by, Mountain Copper. I have always looked upon this as a very forced derivation, inaſmuch as we do not thereby diſtinguiſh orichalcum from any other kind of copper; moſt copper mines, in every part of the world, being found in mountainous countries. If it ſhould be thought, that ſome one particular mountain, either in Greece or Aſia, formerly produced an ore, which being ſmelted yielded a copper of the colour of gold, and that this copper was called orichalcum, or the mountain copper, it is much to be wondered at, that neither the poets nor the philoſophers of antiquity have beſtowed a ſingle line in its commendation; for as to the *Atlantis* of *Plato*, before mentioned, no one, it is conceived, will build an argument for the exiſtence of natural orichalcum, on ſuch an uncertain foundation: and, if there had been any ſuch mountain, it is probable, that the copper it produced would have retained its name, juſt as at this time of day we ſpeak of *Ecton* copper in *Staffordſhire*, and of *Paris-mountain* copper in *Angleſey*.

Some men are fond of etymological inquiries, and to them I would ſuggeſt a very different derivation of orichalcum. The Hebrew word *or*, *aur*, ſignifies *light*, *fire*, *flame*; the Latin terms *uro* to burn, and *aurum* gold, are derived from it, inaſmuch as gold reſembles the colour of flame; and hence, it is not improbable, that orichalcum may be compoſed of an Hebrew, and a Greek term, and that it is rightly rendered, *flame-coloured copper*. In confirmation of this it may be obſerved, that the Latin epithet *lucidum*, and the Greek one φαεινον, are both applied to orichalcum by the ancients; but I would be underſtood to ſubmit this conjecture, with great deference, to thoſe who are much better ſkilled, than I am, in etymological learning.

ESSAY III.

Of Gun-metal—Statuary-metal—Bell-metal—Pot-metal, and Speculum-metal.

BESIDES braſs there are many other metallic mixtures, into which copper enters as the principal ingredient; the moſt remarkable of theſe are *gun-metal*, *bell-metal*, *pot-metal*, and *ſpeculum-metal.*

It has been remarked of Queen Elizabeth, that ſhe left more braſs ordnance at her death, than ſhe found of iron on her acceſſion to the throne. This muſt not be underſtood, as if gun-metal was in her time made chiefly of braſs; for the term braſs, was ſometimes uſed to denote copper, and ſometimes a compoſition of iron, copper, and calamine, was called braſs, and we at this day commonly ſpeak of braſs cannon, though braſs does not enter into the compoſition uſed for the caſting of cannon. *Aldrovandus* * informs us, that one hundred pounds weight of copper with twelve of tin, made *gun-metal*; and that, if inſtead of twelve, twenty pounds weight of tin was uſed, the metal became *bell-metal*. The workmen were accuſtomed to call this compoſition, metal or *bronze*, according

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* Aldrov. p. 108.

ing as a greater or a leſs proportion of tin had been uſed. Some individuals, he ſays, for the ſake of cheapneſs, uſed braſs or lead inſtead of tin, and thus formed a kind of bronze for various works. I do not know whether connoiſſeurs eſteem the metal, of which the ancients caſt their *ſtatues*, to be of a quality ſuperior to our modern bronze; but if we ſhould wiſh to imitate the *Romans* in this point, Pliny has enabled us to do it; for he has told us, that the metal for their ſtatues, and for the plates on which they engraved inſcriptions, was compoſed in the following manner. They firſt melted a quantity of copper; into the melted copper, they put a third of its weight of old copper, which had been long in uſe; to every hundred pounds weight of

this

this mixture, they added twelve pounds and an half of a mixture, compoſed of equal parts of lead and tin *.

In *Diego Uſano's* Artillery, publiſhed in 1614, we have an account of the different metallic mixtures then uſed for the caſting of cannon, by the principal gun-founders in Europe.

Copper	160—	100—	100—	100	parts.
Tin	10—	20—	8—	8	
Braſs	8—	5—	5—	0	

The beſt poſſible metallic mixture cannot be eaſily aſcertained, as various mixtures may anſwer equally well the rude purpoſe to which ordnance is applied. Some mixtures, however, are unqueſtionably better adapted to this purpoſe than other, in ſome particular points. Of two metallic mixtures, which ſhould be equally ſtrong, the lighteſt would have the preference: at the laſt ſiege of *Prague*, part of the ordnance of the beſiegers, was melted by the frequency of the firing; the mixture of which it was made, contained a large portion of lead, and it would have been leſs prone to melt, and conſequently preferable had it contained none.

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* Hiſt. Nat. L. XXXIV. S. XX.

Woolwich, I believe, is the only place in England, where there is a foundery for the caſting of braſs cannon. The metallic compoſition there uſed, conſiſts of *copper* and *tin*. The proportion, in which theſe two metals are combined, is not always the ſame, becauſe the copper is not always of equal purity, and the fineſt copper requires the moſt tin: they ſeldom uſe more than 12, or leſs than 8 parts of tin to every 100 of copper. This metallic mixture is ſold, before caſting, for 75*£*. a ton, and *Government* pays for caſting it 60*£*. a ton. The guns of the *Eaſt India Company* are leſs ornamented than thoſe of Government, on that and other accounts they are caſt for 40*£*. a ton. I have here put down the weights of the braſs ordnance, now moſt generally in uſe as caſt at Woolwich.

Weight of braſs cannon now in uſe.

	C.	q.	lb.
42 pounders -	61	2	10
24 - - -	51	0	0
12 - - -	29	0	0
6 - - -	19	0	0

Theſe were on board the Royal George in 1780, but had been removed,

moved, I believe, before ſhe was loſt.

Battering cannon.

42 pounders	61	2	10
32	55	2	10
24	51	0	0
18	48	0	0
12	29	0	0
9	25	0	0
6	19	0	0

Field pieces.

24 pounders	16	3	13
12	8	3	8
6	4	3	10
3	2	3	10

Howitzers.

10 inches	31	2	16
8	12	1	16
5½	4	0	18

Mortars (Land Service).

13 inches	25	0	0
10	10	2	8
8	4	0	10
$5\frac{1}{2}$	1	1	0
$4\frac{2}{5}$	0	3	0

Mortars (Sea Service).

13 inches	81	1	8
10	32	3	7

In caſting theſe pieces of cannon, they generally make the thickneſs of the ſides near the muzzle half the diameter of the ſhot, and at the touch-hole, or charging cylinder, three fourths of the diameter. Braſs cannons are dearer than ſuch as are made of iron; and, which is a diſadvantage, they give a louder report at the time of exploſion, ſo as to occaſion a tingling in the ears of the perſons on ſhipboard, which takes away for a time the faculty of hearing.

Cannon might be caſt of copper alone; but the mixture of tin and copper is harder and denſer, and leſs liable to ruſt than pure copper is, and upon theſe accounts it is preferable to copper. Tin melts with a ſmall degree of heat, copper requires a very great heat to melt it; a mixture of copper and tin melts much eaſier than pure copper, and upon this account alſo, a mixture of copper and tin is preferred to pure copper, not only for the caſting of cannon, but of ſtatues, &c.; for pure copper, in running through the various parts of the moulds, would loſe ſo much of its heat as to ſet before it ought to do.

Bell-metal conſiſts alſo of tin and

copper. Authors do not agree in the proportions: ſome ordering 1 part of tin to be melted with 4 parts of copper *; others making the proportion for bell-metal to be the ſame as that for gun-metal, or 1 part of tin to about 10 parts of copper, to which they order a little braſs to be added †. It may in general be obſerved, that a leſs proportion of tin is uſed for making church bells than clock bells, and that they add a little zinc for the bells of repeating watches, and other ſmall bells. This zinc becomes manifeſt on melting theſe bells, by the blue flame which it exhibits.

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* Pemb. Chem. p. 321.

† Waller. Miner. Vol. II. p. 242. New. Chem. by Lewis, p. 66. Macq. Chem. Vol. I. p. 70. Eng. Tranſ.

There is a very remarkable experiment mentioned by *Glauber* *. — "Make," ſays he, "two balls of copper, and two of pure tin not mixed with lead, of one and the ſame form and quantity, the weight of which balls obſerve exactly; which done, again melt the aforeſaid balls or bullets into one, and firſt the copper, to which melted add the tin, leſt much tin evaporate in the melting, and preſently pour out the mixture melted into the mould of the firſt balls, and there will not come forth four, nor ſcarce three balls, the weight of the four balls being reſerved." This ſubject has been proſecuted ſince Glauber's time †, and it has been diſcovered,

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* Glauber's Works, fol. Ed. 1689. p. 81.

† Gellert's Chy. Metal. & Chem. Dict. art. Allay.

covered, that when metallic ſubſtances are melted together, it ſeldom happens that a cubic inch of each of the two ingredients, will form a maſs exactly equal to two cubic inches; the mixture will in ſome inſtances be greater, and in other leſs than two cubic inches. In the inſtance of tin and copper, where the bulk of the mixture is ſo much leſs than the ſum of the bulks of the two component parts, it might be expected that the compound metal would poſſeſs properties, not merely intermediate between thoſe of copper and tin, but eſſentially different from them both. And accordingly we find, that this mixture is not only more brittle, more hard, and more ſonorous, than either copper or tin; but it is more denſe alſo, than either of them; a cubic foot of it weighing, not only more than a cubic foot of tin, but than a cubic foot of copper itſelf.

Pot-metal is made of copper and lead, the lead being one fourth or one fifth the weight of the copper. In Pliny's time pot-metal (*ollaria temperatura*) was made of a pound and an half or two pounds of lead, and an equal portion of tin, mixed with 100 parts of copper. Copper and lead ſeem not to be combined together in the ſame way that copper and tin are, for when pot-metal is expoſed to a melting heat, the lead is firſt fuſed, and ſhews itſelf in little drops over the ſurface of the pot-metal, whilſt the copper remains unfuſed.

It is reported of *James* II. that he melted down and coined all the braſs guns in Ireland, and afterwards proceeded to coin the pewter with this inſcription — *Melioris teſſera fati.* — The *Congreſs* in *America* had recourſe to the ſame expedient; they coined ſeveral pieces of about an inch and half in diameter, and of 240 grains in weight; on one ſide of which was inſcribed in a circular ring near the edge — *Continental Currency*, 1776 — and within the ring a riſing ſun, with — *fugio* — at the ſide of it, ſhining upon a dial, under which was — *Mind your buſineſs.* — On the reverſe were thirteen ſmall circles joined together like the rings of a chain, on each of which was inſcribed the name of ſome one of the thirteen ſtates; on another circular ring, within theſe, was inſcribed — *American Congreſs* — and in the central ſpace — *We are One.* — I have been particular in the mention of this piece of money, becauſe like the leaden money which was ſtruck at *Vienna*, when that city was beſieged by the Turks in 1529, it will ſoon become a great curioſity. I eſtimated the weight of a cubic foot of this Continental currency, it was equal to 7440 ounces: this exceeds the weight of a cubic foot of our beſt ſort of pewter, and falls ſhort of that of our worſt; I conjecture that the metal of the Continental currency conſiſted of 12 parts of tin and of 1 of lead. Plautus *, and other Roman authors, make mention of leaden money; ſome are of opinion that we ought to underſtand by that expreſſion, copper mixed with lead; but that cannot be the meaning, if it be true, that the Romans did not mix lead with their copper currency till the age of Septimius Severus, for Plautus lived many years before that emperor. I will not enter into the controverſy, and I have introduced this obſervation relative to the leaden money of the Romans, merely to ſhew the correſpondence, which ſome of the Roman copper medals bore to our pot-metal; for thoſe which were ſtruck after the age of *Septimius Severus*, being expoſed to a proper degree of heat, ſweat out drops of lead, as it has been remarked our pot-metal does: but medals of greater antiquity have no ſuch property *.

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* Tace ſis, faber, qui cudere ſoles plumbeos nummos. Plau. Moſ. A. IV. S. II. L. XI. et Caſin. A. II. S. III. L. XL. et Mart. L. X. E. LXXIV.

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* Illi enim qui ſtudii hujus amore teuentur, cum monetam æream ante Septimium Severum

The ſex have in all ages uſed ſome contrivance or other to enable them to ſet off their dreſs to the beſt advantage; and the men were probably never without their attention to that point. We find *Juvenal*[*] ſatirizing the emperor *Otho* for making a *ſpeculum* part of his camp equipage.

Res memoranda novis annalibus, atque recenti
Hiſtoria, *ſpeculum* civilis ſarcina belli.

Homer, in deſcribing *Juno* at her toilet[†], makes no mention of a ſpeculum;

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rum cuſam igne probent nihil plumbi inde ſecerni deprehendunt. Aliter autem comparata ſunt numiſmata poſt ætatem Severi cuſa, quippe ex quibus guttulæ quædam plumbi, vel modico ignis calore diverſis in locis exprimuntur. Savot de Num. Ant. P. II. C. I. Theſe pot-metal medals were probably *caſt*.

[*] Sat. II. l. 102.

[†] Il. L. XIV. l. 170.

lum; but in *Callimachus* * we ſee, though it ſuited not the majeſty of *Juno*, nor the wiſdom of *Pallas* to uſe a ſpeculum before they exhibited their perſons to *Paris*, who was to determine the prize of beauty; that *Venus*, on the ſame occaſion, had frequent recourſe to one, before ſhe could adjuſt her locks to her own ſatisfaction. The moſt ancient account we have of the uſe of ſpecula is that in *Exodus* (xxxviii. 8.) "And he made the laver of braſs [copper, or a mixture of copper and tin] and the foot of it of braſs of the *looking glaſſes* of the women." The Engliſh reader may wonder how a veſſel of *braſs* could be made out of looking *glaſſes*, the Hebrew word might properly be rendered by *ſpecula*, or *metallic mirrors*.

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* Hym. in Lavac. Pallad.

The *Jewiſh* women were, probably, *preſented* with theſe mirrors, as they were with other articles of value by their *Egyptian* neighbours, when they left the country; for it was the cuſtom of the Egyptians, when they went to their temples, to carry a mirror in their left hand *: it is remarkable, that the *Peruvians*, who had ſo many cuſtoms in common with the *Egyptians*, were very fond alſo of mirrors; which they ordinarily formed of a ſort of *lava* that bore a fine poliſh.

Pliny † ſays, that the beſt ſpecula were anciently made at *Brunduſium* of copper and tin; that *Praxiteles*, in the time of *Pompey* the Great, was the firſt who made one of ſilver, but that ſilver ones were in his time become ſo common, that they were uſed even by the maid ſervants. The metallic mixture of tin and copper was known long before the age of Pliny; it is mentioned by Ariſtotle *, incidentally, when he is deſcribing a method of rendering copper white, but not by tin; and from its great utility, it will probably never fall into diſuſe. We have ceaſed, indeed, ſince the introduction of glaſs mirrors, to uſe it in the way the ancients did; but it is ſtill of great uſe amongſt us, ſince the ſpecula of reflecting teleſcopes are commonly made of it. Mr. *Mudge* has aſcertained †, not only the beſt proportion in which the copper and tin ſhould be mixed together, but has found out alſo a method of caſting the ſpecula without pores. He obſerves, that the perfection of the metal, of which the ſpeculum ſhould be made, conſiſts in its hardneſs, whiteneſs, and compactneſs. When the quantity of tin is a third of the whole compoſition, the metal then has its utmoſt whiteneſs; but it is at the ſame time rendered ſo hard that it cannot be poliſhed without having its ſurface ſplintered and broke up. After many experiments, he at length found that fourteen ounces and one half of grain-tin *, and two pounds of copper

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* Cyril. de Ado.

† Hiſt. Nat. L. XXXIII. S. XLV.

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* De Mirab.

† Philoſ. Tranſ. 1777. p. 296.

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* "*Grain-tin* is worth ten or twelve ſhillings per hundred more than mine tin, becauſe it is ſmelted from a pure mineral by a *charcoal* fire; whereas *mine tin* is uſually corrupted with ſome portion of mundick, and other

per made the beſt compoſition; an addition of half an ounce more tin rendered the compoſition too hard to be properly poliſhed. The caſting the metal ſo as that it may be compact and without pores, is a matter of the greateſt conſequence; he hit upon the manner of doing it by accident. His uſual way of caſting a ſpeculum metal, was to melt the copper and to add the tin to the melted copper; the maſs when caſt was ſeldom free from pores. After having uſed all his copper in trying experiments to remedy this defect, he recollected

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other minerals, and is always ſmelted with a bituminous fire, which communicates a harſh, ſulphureous, injurious quality to the metal." Pryce, Min. Cornu. p. 137.——Mr. Mudge probably uſed what is called *grain-tin* in the ſhops, or the pureſt ſort, which is uſually ſold in pieces like icicles.

collected that he had ſome metal which had been reſerved, when one of the bells of St. Andrew had been re-caſt: he added a little freſh tin to it, and caſting a metal with it, it turned out free from pores, and in all reſpects as fine a metal as he ever ſaw. Upon conſidering this circumſtance, he proceeded to form a metallic maſs in the uſual way, by adding tin to melted copper, this maſs was porous, it was in the ſtate of the bell-metal he had tried, and upon re-melting it, it became, as the bell-metal had done, compact and free from pores. He accounts for this difference by obſerving, that the heat neceſſary to melt copper, calcines part of the tin, and the earthy calcined particles of the tin, being mixed in the maſs of the metal, render it porous, but the compoſition of tin and copper, melting with leſs than half the heat requiſite to melt the copper, the tin is not liable to be calcined in the ſecond melting, as in the firſt. I am rather diſpoſed to think, that the abſence of the pores is to be attributed to the more *perfect fuſion* of the metal: for I have obſerved at *Sheffield*, that the ſame weight of melted ſteel, will fill the ſame mould to a greater or leſs height, according to the degree of fuſion the ſteel has been in; if it has been in a ſtrong heat, and thin fuſion, the bar of caſt ſteel will be an inch in 36 ſhorter than when the fuſion has been leſs perfect. Upon breaking one of the bars, which had been made from ſteel in an imperfect fuſion, its inſide was full of blebs; a ſhorter bar of the ſame weight and diameter, which had been in a thin fuſion, was of a cloſer texture. Now the mixture of tin and copper melts far eaſier than copper does, and is likely on that account, to be in a thinner fuſion when it is caſt.

It may deſerve to be remarked, and I ſhall have no other opportunity of doing it, that the melting or *caſting* of ſteel was introduced at Sheffield, about forty years ago, by one *Waller* from London, and was afterwards much practiſed by one *Huntſman*, from whom ſteel ſo prepared, acquired the name of *Huntſman's caſt ſteel.* It was at firſt ſold for fourteen pence, but may now be had for tenpence a pound; it coſts three-pence a pound in being melted, and for drawing ingots of caſt ſteel into bars of the ſize of raſors, they pay only ſix ſhillings for a hundred weight, and ten ſhillings for the ſame quantity when they make the bars into a ſize fit for ſmall files, &c. The caſt ſteel will not bear more than a red heat, in a welding heat in runs away under the hammer like ſand. Before the art of caſting ſteel was introduced at Sheffield, all the caſt ſteel uſed in the kingdom was brought from Germany; the buſineſs is carried on at Sheffield with greater advantage, than at moſt other places, for their manufactures furniſh them with great abundance of broken tools, and theſe bits of old ſteel they purchaſe at a penny a pound and melt them, and on that account they can afford their caſt ſteel cheaper than where it is made altogether from freſh bars of ſteel.

ESSAY IV.

Of Tinning Copper—Tin—Pewter.

UNHAPPILY for mankind, the fatal accidents attending the uſe of copper veſſels, in the preparation of food and phyſick, are too common, and too well atteſted to require a particular enumeration or proof: ſcarce a year paſſes, but we hear of ſome of them, eſpecially in foreign countries; and many ſlighter maladies, originating from the ſame ſource, daily eſcape obſervation, or are referred to other cauſes in our own.

In conſequence of ſome repreſentations from the *College of Health*, the uſe of *copper* veſſels in the fleets and armies of *Sweden* was aboliſhed in the year 1754; and *tinned iron* was ordered to be ſubſtituted in their ſtead *. The Swediſh government deſerves the greater commendation for this proceeding, as they have great plenty of excellent copper in the mines of that country, but no tin. An intelligent ſurgeon ſuggeſted, in 1757, the probability of the uſe of copper veſſels in the navy, being one of the cauſes of the ſea ſcurvy, and recommended the having them changed for veſſels of iron; he remarked, that of the 200 ſail of ſhips which went to ſea from *Scarborough*, moſt of them uſed iron pots for boiling their victuals, and that the ſymptoms called *highly ſcorbutic*, were never ſeen, except in ſome few of the larger ſhips in which copper veſſels were uſed *. Notwithſtanding this hint, and the example of Sweden, I do not know that any other European ſtate has prohibited the uſe of copper veſſels for the dreſſing of food on board their ſhips; but many of them have ſhewn a laudable attention to prevent its malignity; by inquiring into the beſt manner of covering its ſurface with ſome metallic ſubſtance, leſs noxious, or leſs liable to be diſſolved than itſelf. This operation is uſually called *tinning*, becauſe tin is the principal ingredient in the metallic mixture, which is made uſe of for that purpoſe; and, indeed, ſince the year 1755, it has been frequently, in this country at leaſt, uſed alone. In that year, *The Society for the Encouragement of Arts, Manufactures and Commerce*, thought it an object deſerving their attention, to offer a premium for the tinning copper and braſs veſſels with pure tin, without lead or any other alloy. There were ſeveral candidates for the premium; and ſince that time, the tinning with pure tin, and hammering it upon the copper, has become very general in England. But this mode of tinning does not appear to have been known, or at leaſt it does not appear to have been adopted in other countries; for in the Memoirs of the Royal Academy at *Bruſſels*, for the year 1780, *M. L'Abbé Marci* recommends, as a new practice, the tinning with pure *block-tin* from England; though, he ſays, block-tin is a compound body, even as it is imported from England; but he thinks it a much ſafer covering for copper than what is ordinarily uſed by the braziers; and he gives ſome directions as to the manner of performing the operation. The *Lieutenant-General* of the Police at *Paris*, gave it in commiſſion to the College of Pharmacy, in 1781, to make all the experiments which might be neceſſary for determining — whether pure tin might or might not be uſed for domeſtic purpoſes, without danger to health? The reſearches which were made, in conſequence of this commiſſion, by Meſſieurs *Charland* and *Bayen* with great ability, were publiſhed by order of the French government; and they have greatly contributed to leſſen the apprehenſions relative to the uſe of tin, which had been generally excited by the experiments of *Marggraf*, publiſhed firſt in the *Berlin* Memoirs for 1747. That gentleman, in purſuing an experiment of *Henckel*, who firſt diſcovered arſenic in tin, ſhewed, that, though there was a ſort of tin, which being fluxed from an ore of a particular kind, contained no arſenic, the *Eaſt India* tin, which is generally eſteemed the pureſt of all others, contained a great deal of arſenic. *M. Boſc d'Antic* in his works, which were publiſhed at Paris, 1780, ſets aſide the authority of *Marggraf*, *Cramer*, and *Hellot*, relative to the exiſtence of arſenic in tin; and is not only of opinion, that the *Corniſh* tin does not conceal any arſenic in its ſubſtance, but that its uſe as kitchen furniture is not dangerous. Meſſieurs Charland and Bayen found that neither *Eaſt India*, nor the *pureſt* ſort of *Engliſh* tin, contained any arſenic; but that the Engliſh tin, uſually met with in commerce, did contain arſenic; though in ſo ſmall a proportion that it did not amount, in that ſpecies of tin which contained the moſt of it, to more than one grain in an ounce; that is, it did not conſtitute more than one five-hundredth and ſeventy-ſixth part of the weight of the tin, there being 576 grains in a

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* Mem. de l'Acad. de Pruſſe par M. Paul. Vol. IV. Diſ. Prel. p. 63.

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* Medical Obſerv. by a Society of Phy. in Lond. Vol. II. p. 1.

French ounce. This proportion of arſenic is ſo wholly inconſiderable, that it is very properly concluded, that the internal uſe of ſuch ſmall portions of tin, as can mix themſelves with our food, from being prepared in tinned veſſels, can be in no ſenſible degree dangerous on account of the arſenic which the tin may contain. But though tin may not be noxious, on account of the arſenic which it holds, it ſtill remains to be decided, whether it may not be poiſonous of itſelf; as lead is univerſally allowed to be, when taken into the ſtomach. The large quantities of tin, which are ſometimes given in medicine with much ſafety, and the conſtant uſe which our anceſtors made of it in plates and diſhes, before the introduction of china or other earthen ware, without experiencing any miſchief, render all other proof of the innocent nature of pure tin ſuperfluous. And hence it may be proper to add a few obſervations concerning the purity of tin.

The ores of metallic ſubſtances, often contain more ſubſtances than that particular one, from which they receive their denomination. *M. Eller* of Berlin, had in his collection an ore, which contained *gold*, and *ſilver*, and *iron*, and *quickſilver*, cloſely united together in the ſame maſs. Lead ore, it has been remarked, ſo often contains ſilver, that it is ſeldom found without it; it is often alſo mixed with a ſulphureous pyrites, which is a ſort of iron ore, and with black jack, which is an ore of zinc; ſo that *lead*, and *ſilver*, and *iron*, and *zinc*, are commonly enough to be met with in the ſame lump of lead ore. Tin ore, in like manner, though it is ſometimes unmixed, is often otherwiſe; it frequently contains both tin, and iron, and copper. The fire with which tin ore is ſmelted, is ſufficiently ſtrong to ſmelt the ores of the other metals which are mixed with it; and hence the reader may underſtand, that, without any fraudulent proceeding in the tin ſmelter, there may be a variety in the purity of tin, which is expoſed to ſale in the ſame country; and this variety is ſtill more likely to take place, in ſpecimens of tin from different countries, as from the *Eaſt Indies*, from *England*, and from *Germany*. This natural variety in the purity of tin, though ſufficiently diſcernible, is far leſs than that which is fraudulently introduced. Tin is above five times as dear as lead; and as a mixture conſiſting of a large portion of tin with a ſmall one of lead, cannot eaſily be diſtinguiſhed from a maſs of pure tin; the temptation to adulterate tin is great, and the fear of detection ſmall. In *Cornwall*, the purity of tin is aſcertained, before it is expoſed to ſale, by what is called its *coinage:* the tin, when ſmelted from the ore, is poured into quadrangular moulds of ſtone, containing about 320 pounds weight of metal, which, when hardened, is called a *block* of tin; each block of tin is coined in the following manner: — "the officers appointed by the Duke of Cornwall, aſſay it, by taking off a piece of one of the under corners of the block, partly by cutting and partly by breaking; and if well purified, they ſtamp the face of the block with the impreſſion of the ſeal of the Duchy, which ſtamp is a permiſſion for the owner to ſell, and at the ſame time an aſſurance that the tin ſo marked has been purpoſely examined, and found merchantable *." This rude mode of aſſay, is not wholly improper, for if the tin be mixed with lead, the lead will by its ſuperior weight ſink to the bottom, and thus be liable to be diſcovered, when the bottom corner of the block is examined. But though the ſeal of the Duchy may be ſome ſecurity to the original purchaſers of block tin, it can be none at all to thoſe foreigners who purchaſe our tin from

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* Borlaſe's Nat. Hiſt. of Corn. p. 183.

from *Holland*; for, if we may believe an author of great note,—"in Holland every tin founder has Engliſh ſtamps, and whatever his tin be, the inſcription, block tin, makes it paſs for Engliſh [*]." This foreign adulteration of Engliſh tin may be the reaſon that *Muſſchenbroeck*, who was many years Profeſſor of Natural Philoſophy at Utretch, puts the ſpecific gravity of what he calls *pure tin* equal to 7320, but that of Engliſh tin, and he has been followed by *Wallerius*, equal to 7471 [†]; for it will appear preſently, that ſuch ſort of tin muſt-have contained near one tenth of its weight of lead.

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[*] Newman's Chem. by Lewis, p. 89.

[†] Muſſchen. Eſſ. de Phyſ. 1739. French Tranſ. Wallerii Min. Vol. I. p. 154. There is a very good Table of Specific Gravities, publiſhed in the ſecond volume of Muſſchenbroeck's *Introductio ad Philoſophiam Naturalem*, 1763, in which the author does more

Weight of a cubic foot of Engliſh tin, according to different authors.

Cotes, Ferguſon, Emerſon	7320 oz. avoir.
Boerhaave's Chem. by Shaw	7321
Muſſchenbroeck & Wallerius	7471
Martin - -	7550

From the following experiments it may appear probable, that not one of theſe authors, in eſtimating the ſpecific gravity of tin, has uſed the pureſt ſort, but rather a mixture of that with lead, or ſome other metal.

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more juſtice to Engliſh tin, putting the weight of a cubic foot of the *pureſt* ſort equal to 7295 avoir. oun. One ſpecimen of the pureſt ſort of *Malacca* tin gave 7331, and another 6125 ounces a cubic foot, which is the lighteſt of all the tins which he examined.

A block of tin, when it is heated till it is near melting, or after being melted, and before it becomes quite fixed, is ſo brittle that it may be ſhattered into a great many long pieces like icicles, by a ſmart blow of an hammer*: tin in this form is called by our own manufacturers *grain tin*, by foreigners *virgin tin*, or *tears* of tin: and they tell us, that its exportation from Britain is prohibited under pain of death †. The tin which I uſed in the following experiments, was of this ſort, but I firſt melted it, and let it cool gradually; a circumſtance, I ſuſpect, of ſome conſequence in determining the ſpecific gravity not only of tin, but of other metals. I have put down in the following table, the ſpecific gravity of this tin, and of the lead I mixed with it by fuſion, and of the ſeveral mixtures when quite cold; the water in which they were weighed was 60°.

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* This property is not peculiar to tin, I have ſeen maſſes of lead which, under ſimilar circumſtances, exhibited ſimilar appearances, and it has been obſerved, that zinc, when heated till it is juſt ready to be fuſed, is brittle.

† Ency. Fran. and Mr. Baumé calls it étain en roche à cauſe que ſa forme reſemble

Weight

à des ſtalactites; he ſays alſo, that its exportation is prohibited, but that he does not ſee the reaſon for the prohibition, as it is not more pure than Corniſh tin: and in this obſervation he is right, it is nothing but Corniſh tin in a particular form. Chym. par M. Baumé, Vol. III. p. 422.

Weight of a cubic foot of lead, tin, &c.

Lead - -	11270 oz. avoir.
Tin - -	7170
Tin 32 parts, lead 1	7321
Tin 16 — lead 1	7438
Tin 10 — lead 1	7492
Tin 8 — lead 1	7560
Tin 5 — lead 1	7645
Tin 3 — lead 1	7940
Tin 2 — lead 1	8160
Tin 1 — lead 1	8817

Blocks of tin are often melted by the pewterers into ſmall rods; I think the rods are not ſo pure, as the grain tin; at leaſt, I found that a cubic foot of the ſpecimen I examined, weighed 7246 ounces; but even this ſort exceeds in purity any of the kinds examined by the authors above mentioned. Chemiſtry affords certain methods of diſcovering the quantity of lead with which tin is alloyed, but theſe methods are often troubleſome in the application; an enlarged table, of the kind of which I have here given a ſpecimen, will enable us to judge with ſufficient preciſion of the quantity of lead contained in any mixture of tin and lead, of which we know the ſpecific gravity. Pewterers, however, and other dealers in tin, uſe not ſo accurate a method of judging of its purity, but one founded on the ſame principle; for the ſpecific gravities of bodies being nothing but the weights of equal bulks of them, they caſt a bullet of pure tin, and another of the mixture of tin and lead, which they want to examine, in the ſame mould;

and the more the bullet of the mixture exceeds the bullet of pure tin in weight, the more lead they conclude it contains.

Pewter is a mixed metal; it conſiſts of tin united to ſmall portions of other metallic ſubſtances, ſuch as lead, zinc, biſmuth, and the *metallic part*, commonly called, *regulus of antimony*. We have three ſorts of pewter in common uſe; they are diſtinguiſhed by the names of *plate — trifle — ley*. The plate pewter is uſed for plates and diſhes; the trifle chiefly for pints and quarts; and the ley-metal for wine meaſures, &c. Our very beſt ſort of pewter is ſaid to conſiſt of 100 parts of tin, and of 17 of regulus of antimony*, though others allow only 10 parts of regulus to 100 of tin*; to this compoſition the French add a little copper. Crude antimony, which conſiſts of nearly equal portions of ſulphur and of a metallic ſubſtance, may be taken inwardly with great ſafety; but the metallic part, or *regulus*, when ſeparated from the ſulphur, is held to be very poiſonous. Yet *plate* pewter may be a very innocent metal, the tin may leſſen or annihilate the noxious qualities of the metallic part of the antimony. We have an inſtance ſomewhat ſimilar to this in ſtandard ſilver, the uſe of which has never been eſteemed unwholeſome, notwithſtanding it contains near one twelfth of its weight of copper. Though ſtandard ſilver has always been conſidered as a ſafe metal, when uſed for culinary purpoſes; yet it is not altogether ſo, the copper it contains is liable to be corroded by ſaline ſubſtances into verdigris. This is frequently ſeen, when common ſalt is ſuffered to ſtay a few days in ſilver ſaltcellars, which have not a gold gilding; and even ſaline draughts, made with volatile ſalt and juice of lemons, have been obſerved to corrode a ſilver tea ſpoon, which had been left a week in the mixture.

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* Med. Tranſ. Vol. I. p. 285.

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* Pemb. Chem. p. 322.

The weight of a cubic foot of each of theſe ſorts of pewter is,

Plate -	7248
Trifle -	7359
Ley -	7963.

If the plate pewter be compoſed of tin and *regulus* of antimony, there is no reaſon to expect, that a cubic foot of it ſhould be heavier than it appears to be; ſince *regulus* of antimony, according to the different ways in which it is made, is heavier or lighter than pure tin. A very fine ſilver-looking metal is ſaid to be compoſed of 100 pounds of tin, 8 of regulus of antimony, 1 of biſmuth, and 4 of copper. The *ley* pewter, if we may judge of its compoſition by comparing its weight with the weights of the mixtures of tin and lead, mentioned in the table, contains not ſo much as a third, but more than a fifth part of its weight of lead; this quantity of lead is far too much, conſidering one of the uſes to which this ſort of pewter is applied; for acid wines will readily corrode the lead of the flagons, in which they are meaſured, into ſugar of lead; this danger is not ſo great with us, where wine is ſeldom ſold by the meaſure, as it is in other countries where it is generally ſold ſo, and their wine meaſures contain, probably, more lead than ours do. Our Engliſh pewterers have at all times made a myſtery of their art, and their caution was formerly ſo much encouraged by the legiſlature, that an act of parliament was paſſed, rendering it unlawful for any maſter pewterer to take an apprentice, or to employ a journeyman who was a foreigner. In the preſent improved ſtate of chemiſtry, this caution is uſeleſs; ſince any one tolerably ſkilled in that ſcience, would be able to diſcover the quality, and quantity of the metallic ſubſtances, uſed in any particular ſort of pewter; and it is not only uſeleſs now, but one would have thought it muſt have been always ſo; whilſt tin, the principal ingredient, was found in no part of Europe in ſo pure a ſtate, nor in ſo great plenty as in England.

Borlaſe and *Pryce*, who have written ſo minutely on the method of preparing the tin in *Cornwall*, are both of them ſilent, as to any operation the tin undergoes ſubſequent to its coinage; nor do they ſay any thing of its being mixed with other metallic ſubſtances previous to its coinage; but aſſure us, that the tin, as it flows from the ore, is laded into troughs, each of which contains about three hundred pounds weight of metal, called ſlabs, blocks, or pieces of tin, in which *ſize* and *form* it is ſold in every market in Europe. Foreigners, however, in general aſſert, that our tin as exported is a mixed metal; and the *French Encyclopediſts* in particular (article *etain*) inform us, on the authority of Mr. *Rouelle*, that the virgin tin is again melted and caſt into iron moulds of half a foot in thickneſs; that the metal is cooled very ſlowly; that when cold it is divided horizontally into three layers; that the uppermoſt, being very ſoft pure tin, is afterwards mixed with copper, in the proportion of 3 pounds of copper to 100 of tin; that the ſecond layer, being of a harſher nature, has 5 pounds of lead added to an 100 of the tin; and that the loweſt layer is mixed with 9 pounds of lead to an hundred of the tin; the whole is then re-melted, and cooled quickly, and this, they ſay, is the ordinary tin of England; and *Geoffroy* had formerly given much the ſame account *. There is, probably, no other foundation for this report, but that pewter has been miſtaken for tin, theſe metals being ſometimes called by the ſame name; and fine pewter being ſometimes made from a mixture of 1 part of copper with 20 or 30 parts of tin.

The mixture generally uſed for the

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* —— fuſores aperto furni oſtiolo, metallum in formas quaſdam ex arena paratas diffluere ſinunt, ibique in maſſas grandiores concreſcit. Superior ſtanneæ maſſæ pars adeo mollis eſt et flexilis ut ſola elaborari nequeat ſine cupri miſcela, trium ſcilicet librarum ſuper ſtanni libras centum. Maſſæ pars media binas tantum cupri libras recipit. Infima vero adeo fragilis eſt et intractabilis, ut cum hujus metalli centum libris plumbi libras octodecim conſociare oporteat. Geoff. Mat. Med. Vol. I. p. 282.

tinning of copper veſſels, conſiſts of 3 pounds of lead, and of 5 pounds of pewter; when a finer compoſition is required, ten parts of lead are mixed with ſixteen of tin; or one part of lead with two of tin; but the proportions in which lead and tin are mixed together, even for the ſame kind of work, are not every where the ſame; different artiſts having different cuſtoms. Veſſels tinned with pure tin, or with the beſt kind of pewter, which contains no lead, do not ſtain the fingers when rubbed with them: whilſt thoſe which are tinned with a compoſition, into which lead enters as a conſtituent part, colour the fingers with a blackiſh tinge.

Zinc was long ago recommended for the tinning of copper veſſels, in preference both to the mixture of tin and lead, and to pure tin *: and zinc certainly has the advantage of being harder than tin, and of bearing a greater degree of heat before it will be melted from the ſurface of the copper; ſo that on both theſe accounts it would, when applied on the ſurface of copper, laſt longer than tin; juſt as tin, for the ſame reaſons, laſts longer than a mixture of tin and lead. But whether zinc makes any part of the compound metal for tinning copper, ſo as to prevent the neceſſity of repeated tinning, for which a patent was granted ſome years ago, is what I cannot affirm. Whatever may be the excellence of that compoſition, or of any other compoſition, which may be invented

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* Mem. de l'Acad. des Scien. a Par. 1742.

vented with reſpect to its durability, and its not contracting ruſt; ſtill it ought not to be admitted into general uſe, till it has been proved, that it is not ſoluble in vegetable acids, or that its ſolutions are not noxious [*]. A method has of late years been introduced at *Rouen*, of applying a coat of zinc upon *hammered* iron ſaucepans. The veſſels are firſt made very bright, ſo that not a black ſpeck can be ſeen; they are then rubbed with a ſolution of ſal ammoniac, and afterwards dipped into an iron pot full of melted zinc, and being taken out, the zinc is found to cover the ſurface of the iron; and if a thicker coat of zinc is wanted, it may be obtained by dipping the veſſel a ſecond time. This kind of covering is ſo hard, that the veſſels may be ſcoured with ſand without its being rubbed off *. Kitchen utenſils, which are made of caſt iron, are uſually tinned to prevent the iron's ruſting; and, as great improvements have been lately made in rendering caſt iron malleable, it is not unlikely, but that tinned iron veſſels may become of general uſe.

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[*] This doubt with reſpect to zinc is ſaid to have been removed.—M. de la Planche, a phyſician at Paris, tried the experiment on himſelf: he took the ſalts of zinc, formed by the vegetable acids, in a much ſtronger doſe than the aliments prepared in copper veſſels, lined with zinc, could have contained, and he felt no dangerous effects from them. Fourcroy's Chem. Vol. I. p. 442.

The common method of tinning, conſiſts in making the ſurface of the copper veſſel quite bright, by ſcraping

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* Journ. de Phy. Decem. 1778.

ing it, and by waſhing it with a ſolution of ſal ammoniac; it is then heated, and the tin, or metallic mixture deſigned for tinning, is melted, and poured into it, and being made quickly to flow over every part of the ſurface of the veſſel, it incorporates with the copper, and, when cold, remains united with it. Roſin or pitch are ſometimes uſed, to prevent the tin from being calcined, and the copper from being ſcaled, either of which circumſtances would hinder the ſticking of the tin.

I had the curioſity to eſtimate the quantity of pure tin, which is uſed in tinning a definite ſurface of copper. The veſſel was accurately weighed before and after it was tinned, its ſurface was equal to 254 ſquare inches; its weight, before it was tinned, was 46 ounces, and its weight, after the operation, was barely 46½ ounces; ſo that half an ounce of tin was ſpread over 254 ſquare inches, or ſomewhat leſs than a grain of tin upon each ſquare inch. How innocent ſoever pure tin may be, yet the tenuity of the coat of it, by which copper veſſels are covered, in the ordinary way of tinning, cannot fail to excite the ſerious apprehenſions of thoſe who conſider it; for in the experiment which I have mentioned, the tin was laid on with a thicker coat than in the common way; inſtead of a grain, I ſuſpect that not a quarter of a grain of tin is ſpread over a ſquare inch in the common way of tinning. A diſcovery has been lately made at Paris of a method of giving to copper or iron a coat of any required thickneſs, by tinning them; the compoſition uſed for the tinning is not mentioned, but it is ſaid that a piece of copper, which in the common way of tinning only abſorbed 21 grains of tin, abſorbed of the new compoſition 432 grains, or above twenty times as much *. Till this diſcovery is generally known, our workmen ſhould ſtudy to cover the copper with as thick a coat as they are able of pure tin. The danger from the *corroſion* or *ſolution* of the tin by vinegar, juice of lemons, or other vegetable acids, if any at all, cannot, it is apprehended, be ſenſibly felt, except in very irritable habits, or where ſour broths, ſauces, or ſyrups are ſuffered to ſtand long in tinned veſſels before they are uſed.

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* L'Eſprit des Journaux, Mai, 1785.

And, indeed, a proper attention to keeping the veſſels clean, might render the uſe of copper itſelf, for the boiling of food, eſpecially of animal food, wholly ſafe. The French may be allowed to excel us in cookery, but we probably excel them in cleanlineſs; for the melancholy accidents attending the uſe of copper veſſels, are much leſs frequent in England than in France; and this difference proceeds, I conjecture, from the ſuperior care of the Engliſh in keeping their veſſels clean, and from the cheapneſs and purity of the tin we uſe in tinning copper. We are not certain that the art of tinning copper veſſels was known to the *Jews*, when they came out of *Egypt*; the veſſels uſed in the temple ſervice, were made of copper by divine appointment; and by being conſtantly kept clean, no inconveniences followed. The wort, from which malt liquor is brewed, is boiled in copper veſſels; the diſtillers and confectioners, prepare their ſpirits and ſyrups in un-tinned veſſels of the ſame metal, without our ſuffering any thing in our health from theſe practices; at leaſt, without our being generally perſuaded that we ſuffer any thing. A new copper veſſel, or a copper veſſel newly tinned, is more dangerous than after it has been uſed; becauſe its pores, which the eye cannot diſtinguiſh, get filled up with the ſubſtances which are boiled in it, and all the ſharp edges of the prominent parts become blunted; and are thereby rendered leſs liable to be abraded.

M. de la Lande, in deſcribing the

cabinet at *Portici*, obſerves, that the kitchen utenſils, which have been dug up at *Herculaneum*, are almoſt all of them made of a compound metal like our bronze, and that many of the veſſels are covered with ſilver, but none of them with tin: and hence he concludes, that the uſeful art of applying tin upon copper, was unknown to the *Romans*; *cet art utile d' appliquer l' etain ſur le cuivre manquoit aux Romains**. By the ſame mode of arguing, it might be inferred, that whatever is not met with in one houſe or town, is not to be found in a whole country: yet, ſhould a town in England, in which there happened to be plenty of tinned, but no plated or ſilvered copper, be ſwallowed up by an earthquake, a future antiquary, employed in digging up its ruins, would make a bad concluſion, if he ſhould thence infer, that the Engliſh underſtood, indeed, at that time the art of applying a covering of tin, but not one of ſilver upon copper. If the ingenious author had recollected what is ſaid in the 34th book of *Pliny's* Natural Hiſtory, he would have ſeen reaſon to believe, that the Romans, at leaſt when Pliny wrote that book, did underſtand the method of tinning copper which is now in uſe; for this great naturaliſt aſſures us in expreſs terms, that tin ſmeared upon copper veſſels, rendered the taſte more agreeable, and reſtrained the virulence of the copper ruſt. It is to no purpoſe to object, that the tin (ſtannum) of Pliny, was a ſub-a ſubſtance different from our tin; for though it ſhould be in ſome meaſure granted, that it was a mixture of lead and ſilver, yet the ſame author tells us, in the ſame place, that white lead (*plumbum album*), by which it is univerſally allowed our tin is meant, was ſo incorporated with copper by boiling, that the copper could ſcarcely be diſtinguiſhed from ſilver *.

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* Voyage d' un Francois en Italie, Vol. VII. p. 120.

Nay,

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* Stannum illitum æneis vaſis, ſaporem gratiorem reddit, et compeſcit æruginis virus, mirumque, pondas non auget—from the weight of the copper not being *ſenſibly* increaſed (for Pliny here ſpeaks popularly) we may infer, that the covering of tin which the copper received was very ſlight, and the art alluded to by Pliny in this place, was probably the ſame with that of tinning now in uſe—album (ſcil. plumbum) incoquitur æreis operibus, Galliarum invento, ita ut vix diſcerni poſſit ab argento, eaque incoctilia vocant.

This

Nay, it appears that the Romans not only uſed pure tin, but the ſame mixture of tin and lead, which ſome of our workmen uſe at this time in tinning veſſels. A mixture of equal parts of tin and lead, they called *argentarium*; a mixture of two parts of lead and one of tin, they call *tertiarium*; and with equal parts of *tertiarium* and tin, that is, with two parts of tin and one of lead, they tinned whatever veſſels they thought fit. They, moreover, applied ſilver upon copper, in the ſame way in which they applied tin upon it*; and they uſed

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This deſcription ſeems to be expreſſive of the manner of tinning, by putting the copper into melted tin, as is practiſed in the tinning of iron plates. Plin. Hiſt. Nat. L. XXXIV. S. XLIII.

* —— deinde et argentum incoquere ſimili modo

uſed this ſilvered copper (I do not call it plated, becauſe copper is plated by a different proceſs) in ornamenting their carriages, and the harneſs of their horſes, as we now uſe plated copper; on this head Pliny obſerves, and a rigid philoſopher will apply the obſervation to ourſelves, that ſuch was the luxury of the Romans, that it was then ſimply reckoned a piece of elegance to conſume in the ornaments of coaches, and in the trappings of horſes, metals, which their anceſtors could not uſe in drinking veſſels, without being aſtoniſhed at their own prodigality: we are not yet, however, arrived at the extravagance of *Nero* and his wife, who ſhod their

modo cœpere equorum maxime ornamentis, &c. Id. ib.

their favourite horſes with gold and ſilver.

Pliny mentions an experiment as characteriſtic of tin — that when melted and poured upon paper, it ſeemed to break the paper by its weight, rather than by its heat; and Ariſtotle, long before Pliny, had remarked the ſmall degree of heat which was requiſite to fuſe *Celtic* (*Britiſh*) tin *. This metal melts with leſs heat than any other ſimple metallic ſubſtance, except quickſilver; it requiring for its fuſion not twice the heat in which water boils; but compoſitions of tin and lead, which are uſed in tinning, melt with a ſtill leſs degree of heat, than what is requiſite to melt ſimple tin: and a mixture compoſed of 5 parts of lead, 3 of tin, and 8 of biſmuth, though ſolid in the heat of the atmoſphere, melts with a leſs degree of heat, than that in which water boils.

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* De Mirab.

ESSAY V.

Of tinning Iron.—Of plating, and gilding Copper.

IRON is tinned in a different manner from copper. In ſome foreign countries, particularly in *France*, *Bohemia*, and *Sweden*, the iron plates, which are to be tinned, are put under a heavy hammer which gives, in ſome works, 76 ſtrokes in a minute: they can in one week, with one hammer, fabricate 4320 plates; the iron is heated in a furnace eight times, and put eight times under the hammer during the operation, and it loſes near an eighth part of its weight. Iron and copper are both of them very apt to be ſcaled by being heated, and they thereby loſe greatly of their weight. Twenty-four hundred weight of pure plate copper, will not, when manufactured into tea-kettles, pans, &c. give above twenty-three hundred weight. Twenty one hundred weight of bar iron will give a ton, when ſplit into rods, but taking into conſideration all iron and ſteel wares, from a needle to an anchor, it is eſtimated that thirty hundred of bar iron will, at an average, yield a ton of wares *.

Thirty

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* See an inſtructive pamphlet, intitled, A Reply to Sir L. O'Brien, by W. Gibbons, 1785.

Thirty hundred weight of *caſt* iron is reduced to twenty, when it is to be made into *wire*; and twenty-ſix to twenty-two, when it is to be made into *bar* iron. Steel ſuffers a much leſs loſs of weight in being hammered, than iron does. *Caſt* ſteel does not loſe above two parts, and *bar* ſteel not above four in 100, when drawn into the ſhape of raſors, files, &c. The iron plates in England, are not hammered, but rolled to proper dimenſions by being put between two cylinders of caſt iron caſed with ſteel. This method of rolling iron is practiſed in *Norway*, when they form the plates with which they cover their houſes; but whether it was invented by the Engliſh, or borrowed from ſome other country, (as many of our inventions in metallurgy have been, eſpecially from Germany,) I have not been able to learn. In the firſt account which I have ſeen of its being practiſed in England, it is ſaid to have been an invention of Major *Hanbury* at *Pontypool*, the account was written in 1697, and many plates had then been rolled *. The *milling* of lead, however, which is an operation of the ſame kind, had been practiſed in the year 1670; for an act of parliament was paſſed in that year, granting unto Sir *Philip Howard*, and *Francis Watſon*, Eſq; the ſole uſe of the manufacture of milled lead, for the ſheathing of ſhips. A book was publiſhed in 1691, intitled, *The New Invention of Milled-Lead for ſheathing of Ships*, &c. It appears from this book, that about 20 ſhips, belonging to the navy, had been ſheathed with lead; but the practice was diſcontinued, on account of the complaints of the officers of the navy, that the rudder irons and bolts under water, had been waſted to ſuch a degree, and in ſo ſhort a ſpace of time, as had never been obſerved upon any *unſheathed* or *wood-ſheathed ſhips.* The perſons then intereſted in ſheathing with lead, publiſhed a ſenſible defence; and amongſt other things, they remarked, that both the Dutch and Engliſh had ever been in the habit of ſheathing the ſtern-poſts and the beards of the rudders with lead or copper; and that the Portugueſe and Spaniards did *then* ſheath the whole bodies of their ſhips, even of their gallions, with lead, and had done it for many years. Copper ſheathing has ſince taken

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* Phil. Tranſ. Ab. Vol. V.

place

place in the navy, but it is ſaid to be liable to the ſame objections which were, above a century ago, made to lead ſheathing. It is preferable, however, to lead, on account of its lightneſs. If the fact ſhould be once well eſtabliſhed, that ſhips ſheathed with lead or copper, will not laſt ſo long as thoſe which are unſheathed, or ſheathed only with wood; it would be a problem well deſerving the conſideration of chemiſts, to inquire into the manner how a metallic covering operates in injuring the conſtruction of the ſhips, and whether that operation is exerted on the iron bolts, or on the timbers of the ſhip. When the iron plates have been either hammered or rolled to a proper thickneſs, they are ſteeped in an acid liquor, which is produced from the fermentation of barley meal, though any other weak acid would anſwer the purpoſe: this ſteeping, and a ſubſequent ſcouring, cleans the ſurface of the iron from every ſpeck of ruſt or blackneſs, the leaſt of which would hinder the tin from ſticking to the iron, ſince no metal will combine itſelf with any earth, and ruſt is the earth of iron. After the plates have been made quite bright, they are put into an iron pot filled with melted tin; the ſurface of the melted tin is kept covered with ſuet or pitch, or ſome fat ſubſtance, to prevent it from being calcined; the tin preſently unites itſelf to the iron, covering each ſide of every plate with a thin white coat; the plates are then taken out of the melted tin, and undergoing ſome further operations, which render them more neat and ſaleable, but are not eſſential to the purpoſe of tinning them, they are packed up in boxes, and are every where to be met with in commerce under the name of tin plates; though the principal part of their ſubſtance is iron, and hence the French have called them *fer blanc*, or white iron: Sir *John Pettus* ſays, that they were with us vulgarly called *latten*; though that word more uſually I think denoted braſs.

Tin is not, but iron is liable to contract ruſt by expoſure to air and moiſture, and hence the chief uſe of tinning iron, is to hinder it from becoming ruſty; and it is a queſtion of ſome importance, whether iron of a greater thickneſs than the plates we have been ſpeaking of, might not be advantageouſly tinned.

I deſired a workman to break off the end of a large pair of pincers, which had been long uſed in taking the plates out of the melted tin; the iron of the pincers ſeemed to have been penetrated through its whole ſubſtance by the tin; it was of a white colour, and had preſerved its malleability. It is uſual to cover iron ſtirrups, buckles, and bridle bits, with a coat of tin, by dipping them, after they are made, into melted tin; and pins, which are made of copper wire, are whitened, by being boiled for a long time with granulated tin in a lye made of alum and tartar. Would the iron bolts uſed in ſhip building, be preſerved from ruſting by being long boiled in melted tin? — Would it be poſſible to *ſilver* iron plates by ſubſtituting melted ſilver for melted tin? I do not know that this experiment has ever been tried; but an intelligent manufacturer will ſee many advantages which would attend the ſucceſs of it.

It is cuſtomary, in ſome places, to alloy the tin, uſed for tinning iron plates, with about one ſeventieth part of its weight of copper; foreigners make a great ſecret of this practice; I do not know whether any of our manufacturers uſe copper, ſome of them I have reaſon to believe do not. Too much copper renders the plates of a blackiſh hue, and if there is too little, the tin is too thick upon the plates; but this thickneſs, though it may render the plates dearer, or the profit of the manufacturer leſs, will make them laſt longer. When the tin is heated to too great a pitch, ſome of the plates have yellowiſh ſpots on them; but the coat of tin is thinner, and more even, when the tin is of a great, than of a moderate heat; and the yellowneſs may be taken away, by boiling the plates for two or three minutes in lees of wine, or, where they cannot be had, ſour ſmall beer, or other ſimilar liquors, may, probably, be uſed with the ſame ſucceſs. The quantity of tin uſed in tinning a definite number of plates, each of a definite ſize, is not the ſame at different manufactories. In ſome fabrics in *Bohemia*, they uſe 14 pounds weight of tin for making 300 plates, each of them being 11$\frac{1}{5}$ inches long by 8$\frac{1}{2}$ broad; according to this account, one pound of tin covers a ſurface of 28$\frac{1}{3}$ ſquare feet:

in other, where the tin is laid on thicker, one pound will not cover above 22 ſquare feet; the thickneſs of the tin, even in this caſe, is ſmall, not much exceeding the one thouſandth part of an inch; though that is near twice the thickneſs which tin has upon copper in the ordinary way of tinning. I have inquired of our Engliſh manufacturers concerning the quantity of tin uſed by them in covering a definite ſurface of iron, and from what I could collect, it is very nearly the ſame with that uſed in Bohemia, from whence we derived the art of tinning, or 28 ſquare feet to a pound of tin.

There are various *tin plate* manufactories eſtabliſhed of late years in different parts of England and Wales. *Saxony*, and part of *Bohemia* formerly ſupplied all the known world with this commodity; but England now exports large quantities of it to Holland, Flanders, France, Spain, Italy, and other places. About the year 1670, *Andrew Yarranton* (he deſerves a ſtatue for the attempt) undertook, at the expence of ſome enterpriſing perſons, a journey into Saxony, in order to diſcover the art of making tin plates; he ſucceeded to his utmoſt wiſhes; and, on his return, ſeveral parcels of tin plates were made, which met with the approbation of the tin men in London and Worceſter *. Upon this ſucceſs, preparations were made for ſetting up a manufactory, by the ſame perſons who had expended their money in making

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* England's Improvement by Sea and Land, by And. Yarranton, Gent. 1698.

ing the diſcovery; but a patent being obtained by ſome others, the deſign was abandoned by the firſt projectors, and the patentees never made any plates; ſo that the whole ſcheme ſeems to have been given up till the year 1720, when the fabricating of tin plates made one of the many very uſeful projects, (though they were mixed with ſome which were impracticable) for which that year will ever be memorable. How ſoon after that year the manufacture of tin plates gained a laſting eſtabliſhment, and where they were firſt made, are points on which I am not ſufficiently informed; an old *Cambridge* workman has told me, that he uſed them at *Lynn* in Norfolk in the year 1730, and that they came from *Pontypool.* The tin men, at the firſt introduction of the Engliſh plates, were greatly delighted with them; they had a better colour, and were more pliable than the foreign ones, which were then, and ſtill continue to be hammered; it being impoſſible to hammer either iron, or copper, to ſo uniform a thickneſs, as theſe metals are reduced to by being rolled. It is ſaid, that a *Corniſh* tin man flying out of England for a murder in 1243, diſcovered tin in *Saxony*, and that before that diſcovery, there was no tin in Europe, except in England *; a *Romiſh* prieſt, converted to be a *Lutheran*, carried the art of making tin plates from *Bohemia* into *Saxony* about the year 1620 †; and *Andrew Yarranton*, as we have ſeen, brought it from Saxony into England about the year 1670; Saxony at that time being the only place in which the plates were made. They are now made not only in England, but in France, Holland, Sweden, &c. though from the cheapneſs of our tin, and the excellency of ſome ſorts of our iron, the greateſt ſhare of the tin plate trade muſt ever center with ourſelves. Our *coal* is another circumſtance, which tends to give Great Britain an advantage, over ſome other countries, in ſuch manufactures as require a great conſumption of fuel. *Wood* was ſcarce in Saxony above a century ago, and it is now ſtill more ſcarce in France. They are beginning, it is ſaid, in that country to uſe coal and coak, or charred pitcoal, called by them *Charbon de terre épuré*, and they have granted a patent to an individual for the preparation of it *. Another individual has begun to diſtil tar from pit-coal, and he gets about 5 pounds weight of tar from an hundred of coal (which is pretty nearly what I ſuggeſted in 1781, as poſſible to be obtained from the ſame quantity, Vol. II. p. 352.). The French † expect great

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* Heylin's Geog.

† Yarranton.

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* Acad. des Scien. a Paris, 1781; where M. Lavoiſier gives an uſeful memoir on the comparative excellencies of pit-coal, coak, wood and charcoal as fuels.—Il ſuit de ces experiences, que pour produire des effets égaux, il faut employer: charbon de terre 600 livres; charbon de terre charbonné 552; charbon de bois mêlé 960; bois de hêtre 1125; bois de chêne 1089.

† Il ſuffit de dire qu'elle peut fournir à la capitale un nouveau chauffage, devenu néceſſaire dans un moment où l'on eſt menacé d'une diſette de bois; qu'elle peut ouvrir dans

great advantage from this mode of depurating coal, but we have nothing to apprehend on that ſcore, for the patriotic zeal of the *Earl of Dundonald* has put us in poſſeſſion of every advantage which can be expected from a diſcovery, which he has had the honour of bringing to perfection.

The plating of copper is performed in the following manner. Upon ſmall ingots of copper they bind plates of ſilver with iron wire, generally allowing 1 ounce of ſilver to 12 ounces of copper. The ſurface of the plate of ſilver is not quite ſo large as that of the copper ingot; upon

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dans le royaume une nouvelle brance de commerce; etablir de nouvelles manufactures; faire valoir des mines, reſtées juſqu' a préſent inutiles. L' Eſprit des Journ. Juillet, 1785.

upon the edges of the copper, which are not covered by the ſilver, they put a little borax; and expoſing the whole to a ſtrong heat, the borax melts, and in melting contributes to melt that part of the ſilver to which it is contiguous, and to attach it in that melted ſtate to the copper. The ingot, with its ſilver plate, is then rolled under ſteel rollers, moved by a water wheel, till it is of a certain thickneſs; it is afterwards further rolled by hand rollers, to a greater or leſs extent, according to the uſe for which it is intended; the thinneſt is applied to the lining of drinking horns. One ounce of ſilver is often rolled out into a ſurface of about 3 ſquare feet, and its thickneſs is about the three thouſandth part of an inch; and hence we need not wonder at the ſilver being ſoon worn off from the ſharp angles of plated copper, when it is rolled to ſo great an extent. Plated copper has, of late years, become very faſhionable for the mouldings of coaches, and for the buckles, rings, &c. of horſe harneſs. It might be uſed very advantageouſly in kitchen utenſils, by thoſe who diſlike the uſe of tinned copper, and cannot afford to be at the expence of ſilver ſaucepans, &c. The ſilver, inſtead of being rolled on the copper to ſo great a thinneſs as it is in moſt works, might be left in kitchen furniture conſiderably thicker, ſo that an ounce of ſilver might be ſpread over one ſquare foot; the ſilver coating would in this caſe ſtill be very thin, yet it would laſt a long time. Fire does not conſume ſilver, and the waſte in thickneſs, which a piece of plate ſuſtains from being in conſtant uſe for a century is not much; as may be collected from comparing the preſent weight of any piece of college plate, which has been daily uſed, with the weight it had an hundred years ago.

I do not know whether any attempt has ever been made to plate copper with tin inſtead of ſilver; I am aware of ſome difficulty, which might attend the operation, but yet it might, I think, be performed; and if it could, we might then have copper veſſels covered with a coat of tin of any required thickneſs, which is the great *deſideratum* in the preſent mode of tinning: but it ought to be remarked, that the thicker the coat of tin, the more liable it would be to be melted off the copper by ſtrong fires.

The art of plating copper has not been long practiſed in England; nor do I know whether it was practiſed at an earlier period in any other country; for the Roman method of ſilvering copper was different, I think, from that now in uſe. *Thomas Bolſover* of *Sheffield*, in the year 1742, was the firſt perſon in England who plated copper; it was applied by him to the purpoſes only of making buttons and ſnuff-boxes: ſoon after it was uſed for various other works; a perſon of the name of *Hoyland*, at Sheffield, was the firſt who made a plated candleſtick.

What is commonly called *French plate*, is not to be confounded with the plated copper of which we have been ſpeaking; for though both theſe ſubſtances conſiſt of copper covered with a thin coat of real ſilver, yet they are not made in the ſame way. In making French plate, copper, or more commonly braſs, is heated to a certain degree, and *ſilver leaf* is applied upon the heated metal, to which it adheres by being rubbed with a proper burniſher. It is evident, that the durability of the plating, muſt depend on the number of leaves which are applied on the ſame quantity of ſurface. For ornaments which are not much uſed, ten leaves may be ſufficient; but an hundred will not laſt long, without betraying the metal they are deſigned to cover, if they be expoſed to much handling or frequently waſhed. After the ſame manner may gold leaf be fixed, either on iron or copper. Gold is applied on ſilver, by coating a ſilver rod with gold leaf; and the rod being afterwards drawn into wire, the gold adheres to it; the ſmalleſt proportion of gold, allowed by act of parliament, is 100 grains to 5760 grains of ſilver; and the beſt double-gilt wire is ſaid to have about 20 grains more of gold to the ſame quantity of ſilver *. It has been calculated, that when common gilt wire is flatted, one grain of gold is ſtretched on the flatted wire to the length of above 401 feet, to a ſurface of above 100 ſquare inches, and to the thinneſs of the 4920090th part of an inch: and *M. de Reaumur* ſays, that a grain of gold may be extended to 2900 feet, and cover a ſurface of more than 1400 ſquare inches; and that the thickneſs of the gold, in the thinneſt parts of ſome gilt wire, did not exceed the fourteen millionth part of an inch *. The gold, when thus applied, is thinner than when ſilver is gilt in the following manner, which is yet reckoned one of the cheapeſt ways, and is uſed in making various toys. Gold is diſſolved in *aqua regia*; and linen rags being dipped into the ſolution, they take up ſome particles of gold; the rags being burned to aſhes, and the aſhes being rubbed on the ſilver, the gold adheres to it, and is rendered viſible by being well burniſhed.

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* Lewis Com. Phil. p. 53.

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* Id. 60.

ESSAY VI.

Of gilding in Or Moulu.—Of the Uſe of Quickſilver in extracting Gold and Silver from Earths.—Of Boerhaave's Experiments on Quickſilver.—Of ſilvering Looking-Glaſſes; and of the Time when that Art was diſcovered.

THERE is another method of applying gold on copper or ſilver, which is much practiſed; it is called gilding in *Or Moulu*. Quickſilver diſſolves gold with great facility: if you ſpread a gold leaf (not what is called Dutch leaf, which is made of braſs) on the palm of your hand, and pour a little quickſilver upon it, you will ſee the quickſilver abſorbing the gold, juſt as water abſorbs into its ſubſtance a piece of ſalt or ſugar. Perſons who have taken mercurial preparations internally, ſeldom fail to obſerve the readineſs with which the mercury tranſudes through their pores, attaching itſelf to the gold of their watches, rings, ſleeve-buttons, or ear rings, and rendering them of a white colour. A piece of gold, of the thickneſs even of a guinea, being rubbed with quickſilver, is ſoon penetrated by it, and thereby made ſo fragile, that it may be broken between the fingers with eaſe: and if more quickſilver be added, the mixture will become a kind of paſte, of different degrees of conſiſtence, according to the quantity of quickſilver which is uſed. A piece of this paſte is ſpread, by ways well known to the artiſts, upon the ſurface of the copper which is to be gilded in *or moulu*, and the metal is then expoſed to a proper degree of heat: quickſilver may be evaporated in a far leſs degree of heat, than what is required to melt either gold or copper; when therefore the mixture of gold and quickſilver is expoſed to the action of fire, the quickſilver is driven off in vapour; and the gold, not being ſuſceptible of evaporation, remains attached to the ſurface of the copper, and undergoing the operations of burniſhing, &c. too minute to be deſcribed, becomes gilt. This method of gilding copper, by means of quickſilver and gold, was known to the Romans *. Quickſilver will not unite with iron, yet by an eaſy operation, the foundation of which has been mentioned (Vol. I. Eſſ. VI.), iron may be gilded in the ſame way, that copper or ſilver may. The iron is firſt to be made bright, and then immerſed in a ſolution of blue vitriol, its ſurface will thereby become covered with a thin coat of copper, and

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* *Æs* inaurari argento vivo, aut certe hydrargyro, legitimum erat. Plin. Hiſt. Nat. L. XXXIII. Pliny underſtood by *argentum vivum*, native quickſilver, which is found in a fluid ſtate in many mines; and by *hydrargyrum*, he underſtood quickſilver ſeparated from its ore by fire; they are the ſame ſubſtance.

and it will then admit the gilding as if its whole ſubſtance was copper.

It is this property which quickſilver has of uniting itſelf with gold, and it does the ſame with ſilver, which has rendered it of ſuch great uſe to the *Spaniards* in *America*. They reduce the earths or ſtones, containing gold or ſilver in their metallic ſtates, into a very fine powder; they mix this powder with quickſilver; and the quickſilver, having the quality of uniting itſelf with every particle of theſe precious metals, but being incapable of contracting any union with any particle of earth, extracts theſe metals from the largeſt portions of earth. The quickſilver which has abſorbed either gold, or ſilver, or a mixture of both, is ſeparated from the ſubſtance it has abſorbed by evaporation;

poration; the quickſilver flies off in vapour, and the ſubſtance remains in the veſſel uſed in the operation. We have no mines of mercury in England; Sir *John Pettus*, indeed, ſays, that a little *cinnabar* is now and then met with in our copper mines; and Mr. *Pennant* obſerves, that quickſilver has been found in its native ſtate on the mountains of Scotland; and I have been ſhewn a piece of clay, ſaid to have been dug near *Berwick*, in which there were ſome mercurial globules; but there are no works at preſent, where mercury is procured in any part of Great Britain: nor are there many mines of mercury in any part of the world. In the Philoſophical Tranſactions for 1665, we have an account of the quickſilver mines of *Idria*, a town ſituated in the country anciently called *Forum Julii*, now *Padria de Friouli*, ſubject to the regency, and included in the circle of the lower *Auſtria* in Germany. Theſe mines have been conſtantly wrought for above 280 years, and are thought, one year with another, to yield above 100 tons of quickſilver. In *Hungary* alſo, there are mines which yield quickſilver, but not ſo copiouſly now as formerly. *Alonſo Barba* mentions ſome quickſilver mines in *America* near *Potoſi* *, which he ſays, God Almighty provided to ſupply the loſs of this mineral, which is very conſiderable in extracting the ſilver from the earths and ſtones with which it is mixed: but the mines of *Almaden* in Spain are the richeſt, and probably have been wrought for the longeſt time of any in the world. Pliny ſpeaks of the *cinnabar* which the Romans, with ſo much jealouſy, annually fetched from Spain, and 'tis very probable that they had it from *Almaden*. M. Juſſieu informs us *, that in 1717, there remained above 1200 tons of quickſilver in the magazines at Almaden, after a great deal had been ſent to *Seville* in order to be exported to *Peru*, where the quickſilver, which is loſt in extracting the ſilver, is ſaid to be at leaſt equal in weight to the ſilver which is extracted. From 1574, when they began to regiſter the quickſilver, which came to *Potoſi* upon the king of Spain's account, to the year 1640, there had been received, according to Alonſo Barba, 204600 quintals, beſides a vaſt quantity irregularly brought in upon other accounts. This application of quickſilver to the extraction of gold and ſilver from the earths in which they are found, has rendered the conſumption of it far more conſiderable ſince the diſcovery of the American mines, than it was amongſt the ancients. *Hoffman* forms a calculation, and concludes, that fifty times as much gold as quickſilver was annually extracted from the bowels of the earth: *Cramer* * admits the truth of this calculation, but inſinuates a ſuſpicion worth attending to — that mercury may often exiſt in minerals, and yet not be diſcovered by miners; ſince in the open fires in which minerals, whoſe

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* Treatiſe on Metals, &c. by Alonſo Barba, Eng. Tranſ. p. 112.

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* Hiſt. de l'Acad. des Scien. 1719.

* Ars Docim. Cram. Vol. I. p. 231

whoſe properties are not known, are uſually examined, the mercury would fly off in fume. Earths or minerals of any kind, containing mercury, are moſt accurately aſſayed by diſtilling them with iron filings; but whether a mineral contains mercury or not, may be eaſily diſcovered, by ſtrewing it, when powdered, on a plate of hot iron, or on a hot brick covered with iron filings, and inverting over it a glaſs of any kind; the mercury, if the mineral contains any, will aſcend and attach itſelf in ſmall globules to the ſide of the glaſs. Mercury is divided by the writers of ſyſtems of mineralogy, into *native mercury*, and *mercury mineraliſed by ſulphur:* native mercury is found in its *running* ſtate, and quite *pure*, as it is ſaid (though this may be doubted from the facility with which mercury diſſolves gold, and ſilver, and other metals) in the mines of *Idria*, *Almaden*, &c.; it is more frequently, however, imbedded in calcareous earths, or clays of different colours, from which it may be ſeparated either by trituration and lotion, the ſmaller globules coaleſcing by mutual contact into larger; or by diſtillation. The running native mercury, which requires no proceſs for its extraction, is more eſteemed, and thought to have ſome peculiar properties which do not belong to that obtained by ſimple diſtillation, though they both come under the denomination of virgin mercury. Mercury mineraliſed by ſulphur, is called *cinnabar*, which ſome ſay is an African word denoting the *blood of a dragon* *. Cinnabar is the moſt common ore of mercury, it is found in an earthy form reſembling red ochre, ſometimes in an indurated ſtate, and, though generally red, it hath been obſerved of a yellowiſh or blackiſh caſt; it is moſtly opake, but ſome pieces are as tranſparent as a ruby. This ore conſiſts of mercury and ſulphur combined together in different proportions; ſome cinnabars yielding as far as 7, other not 3 parts in 8 of their weight of mercury. Sulphur and mercury, being both volatile in a ſmall degree of heat, would riſe together in diſtillation, unleſs ſome ſubſtance, ſuch as quicklime or iron filings, was added to the cinnabar, which, by its ſuperior affinity, unites itſelf with and de-

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* Valmont de Bomare.

detains the ſulphur; whilſt the mercury, not being able to ſupport the heat, is elevated in vapour, and condenſed in various ways in different works. It ſometimes happens, that the coarſer cinnabarine ores are ſo much mixed with calcareous earth, that they require no addition in order to effect the ſeparation of mercury from ſulphur; this is the caſe in the mines of Almaden. The finer kinds of cinnabar, bearing a much higher price than mercury itſelf, are never wrought for mercury, but either uſed in medicine, or when levigated, under the name of *vermilion*, in painting; and often by the women as a ſubſtitute for *carmine*, which is prepared from *cochineal*. *Native* cinnabars are often mixed with ſmall portions of arſenical, vitriolic, or earthy ſubſtances, whence they become of uncertain or dangerous efficacy in medicine; for this reaſon *Geoffroy* recommends the uſe of *factitious* cinnabar, and the native, though formerly in great repute, has been left out of modern diſpenſatories. The fineſt cinnabar we know of is brought from *Japan*; though there is great reaſon to believe, that the *Dutch* impoſe upon the world a home manufacture, under the name of Japan cinnabar; the trade for gold, copper, and cinnabar to Japan is exceeding lucrative, and I believe wholly, as to Europe, in the hands of the Dutch.

Thoſe, who are acquainted with the difficulty of making chemical experiments, will admire the great patience and induſtry with which

Boerhaave inveſtigated the nature of mercury. He was induced to undertake this taſk, from a deſire of verifying or refuting the doctrines of the alchemiſts. Theſe adepts had taught, that mercury was the matter of which all metals conſiſted; and that if it could be cleanſed from ſome original impurities, with which, even in its virgin ſtate, they held it to be polluted, it would then become fit nutriment for the ſeed of every metallic ſubſtance: for, according to them, every metal ſprung from its peculiar ſeed, which, when it met with its proper *pabulum*, in a proper *matrix*, attended with a due foſtering heat, by a vivifying principle multiplied itſelf, and received an augmentation of parts, in a manner ſimilar to that by which plants and animals are dilated in their dimenſions. The inveſtigation of nature is infinite, every age adds ſomewhat to the common ſtock, which renders the labours of preceding ages wholly uſeleſs. We no longer trouble ourſelves with the works of the alchemiſts which remain, nor do we regret ſuch of them, as have been devoured by time, or were burned by the order of Diocletian; nay, even the Herculean labours of Boerhaave are become leſs intereſting to us, and probably never would have been undertaken by him, had he been aware, that mercury would, in a proper degree of cold, become, like other metals, ſolid and malleable. In the Tranſactions of our Royal Society for the year 1733, we meet with Boerhaave's firſt diſſertation upon mercury: his firſt experiments reſpect the change which the pureſt mercury undergoes from continual agitation; he included two ounces, which had been diſtilled above 60 times, in a clean bottle, and faſtening the bottle to the hammer of a fulling mill which was almoſt conſtantly going, found in about eight months time above one eighth of the fluid, ſplendid, inſipid mercury, changed into a black powder, of an acrid braſſy taſte. He next digeſted mercury in a gentle heat (180° of Fahrenheit's ther.) and found it, in a few months, changed into a powder, ſimilar to what had been produced by agitation: both theſe powders in a greater degree of heat were revivified, or became running mercury again. He then enquired into the change which repeated diſtillation could produce; after each operation he found a red acrid powder remaining in the retort; and he obſerves, that this powder was as copiouſly ſeparated, after the mercury had been above 500 times diſtilled, as at firſt; and thence reaſonably concludes, that it ought rather to be attributed to a change of the mercury itſelf, than to any impurity contained in it. This powder, like the preceding, by a ſuperior degree of heat became running mercury; except about a 72d part, which, though fixed in a ſtrong fire and vitrifiable with borax, could not ſupport the action of lead, but vaniſhed entirely, leaving no ſigns of any metallic ſubſtance upon the cupel: this ſhews the little probability of converting mercury into gold or ſilver by the action of a violent fire. In the following year he preſented a memoir to the Royal Academy of Sciences at Paris, upon the ſame ſubject. We there learn, that mercury kept in digeſtion for 15 years, with a conſtant heat of 100 degrees, was not fixed, nor any how changed, except that a little black powder (which by ſimple grinding in a mortar became running mercury) was found floating upon its ſurface. Hence is inferred, the impoſſibility of mercury's being changed in the bowels of the earth into any other metal, the heat in mines ſcarcely ever amounting to 100°. Though it might be impoſſible to change mercury into a metal, yet the philoſophers by fire contended, that mercury, united to a particular kind of ſulphur, entered into the compoſition of all metals, and might by art be extracted from them; lead was of all others thought the moſt likely, and the experiment had been reported to ſucceed by *Van Helmont*, and others; but Boerhaave is poſitive, that nothing can be expected from its combination with ſalts, and lead, or tin. It was ſtill thought by the alchemiſts, that mercury could never be freed from its original impurity, but by being joined to ſome pure body of the ſame nature with itſelf, this they thought gold and ſilver to be. Boerhaave, in order fully to ſubvert their high pretenſions, gave into the Royal Society another paper in the latter end of the year 1736, containing an account of the unchangeableneſs both of mercury and gold, how often ſoever they were diſtilled together. He repeated the diſtillation of mercury from gold above 850 times; the mercury was not in any reſpect changed; its ſpecific gravity was the ſame as at firſt, nor had it loſt the property of being converted into a red powder by a due degree of heat. Theſe were all the tracts which were publiſhed during the life-time of Boerhaave; he died in September, 1738, and left his papers to his two brothers, and after their deaths, they fell into the hands of Charles Frederic Kruſe, phyſician to the Empreſs of Ruſſia; this gentleman hath publiſhed a ſhort extract from Boerhaave's Diary, and promiſes a fuller account of ſtill more laborious operations. We learn from this extract,

tract *, that Boerhaave had diſtilled the ſame mercury 1009 times, and its ſpecific gravity was to that of water, as $13\frac{50}{100}$: 1; whilſt that which had been but once diſtilled was as $13\frac{57}{100}$: 1; a difference which may eaſily be attributed to the different temperatures of the air when the experiments were made, or to other accidental circumſtances, which the accuracy of *Graveſande*, with whom he made the experiment, could not provide againſt.

The mixture of quickſilver with gold, or ſilver, or lead, or tin, or copper, or any other metallic ſubſtance with which it is capable of uniting, is called an *amalgam*, and the operation by which the union is effected, is called *amalgamation.* Authors are not agreed as to the derivation of the word amalgam, ſome think that it is compoſed of two Greek words (αμα and γαμειν) by which the intimate union, or *marriage*, as it were, of the two metals is denoted; others are of opinion, that it ought to be written a *malagma*, and that it is derived from a Greek word (μαλασσω) ſignifying to ſoften, inaſmuch as the metal, be it what it may, is always ſoftened by its union with the mercury. An amalgam, made of four parts of tin and one of quickſilver, in the form of a ball, is uſed by ſome under the pretence of purifying water; it cannot, I think, contribute in any manner to that end; but as the ball is always boiled in the water, the ſeeds of vegetables, or the fiſh ſpawn, or the animalcules, &c. with which water is often polluted, may be precipitated by the action of boiling. But there is another purpoſe to which a mixture of tin and quickſilver is applied with great utility — the ſilvering of looking-glaſſes.

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* Novi Commen. Petropo. Tom. IX. p. 381.

Tin may be beat out into leaves not thicker than paper, called *foils*; on tin foil, fitly diſpoſed on a flat table, quickſilver is poured, and gently rubbed with an hare's foot; it ſoon unites itſelf with the tin, which then becomes very ſplendid, or, as the workmen ſay, is quickened: a plate of glaſs is then cautiouſly ſlid upon the tin leaf, in ſuch a manner as to ſweep off the redundant quickſilver, which is not incorporated with the tin: leaden weights are then placed on the glaſs, and in a little time the quickſilvered tin-foil adheres ſo firmly to the glaſs, that the weights may be removed without any danger of its falling off. The glaſs thus ſilvered is a common looking-glaſs. About two ounces of quickſilver are ſufficient for covering three ſquare feet of glaſs.

It is generally believed, that the art of making looking-glaſſes, by applying to their back ſurface a metallic covering, is a very modern invention. *Muratori* expreſsly ſays, that glaſs *ſpecula*, ſuch he means as are now in uſe, are not of any great antiquity. — Seræ autem antiquitati novimus fuiſſe *ſpecula*, quorum uſus nunquam deſiit; ſed eorum fabricam apud Italos unice forſan Veneti per tempora multa ſervarunt et adhuc ſervant: quæ tamen alio tranſlata nunc in aliis quoque regnis floret[*].—The authors of the *French Encyclopedie*[†] have adopted the ſame opinion, and quoted a *Memoir* printed in the 23d vol. of the Academy of Inſcriptions, &c.—Il eſt d'autant plus étonnant que les anciens n'aient pas connu l'art de rendre le verre propre à conſervir la repréſentation des objets, en appliquant l'etain derriere les glaces, que les progrés de la découverte du verre furent, chez eux, pouſſés fort loin.—Mr. *Nixon*, in ſpeaking of the glaſs *ſpecula* of the ancients, ſays, "before the application of quickſilver in the conſtruction of theſe glaſſes (which I preſume is of no great antiquity) the reflection of images by ſuch ſpecula, muſt have been effected by their being beſmeared *behind*, or tinged *through* with ſome dark colour, eſpecially black *." I have beſtowed more time in ſearching out the age in which the applying a metallic covering to one ſide of a looking-glaſs was introduced, than the ſubject, in the eſtimation of many, will ſeem to deſerve; and, indeed, more than it deſerved in my own eſtimation; but the *difficiles nugæ*, the *ſtultus labor ineptiarum*, when once the mind gets intangled with them, cannot be eaſily abandoned: one feels, moreover, a ſingular reluctance in giving up an unſucceſsful purſuit. The reader would pardon the introduction of this reflection, if he knew how many muſty volumes I turned over before I could meet with any information which could ſatisfy me, in any degree, on this ſubject; I am not yet *quite* ſatisfied, though I take the liberty to ſay, in oppoſition to *Muratori*, and the other reſpectable authorities which I have quoted, that the applying a metallic covering to looking-glaſſes is not a modern invention; — it is probable it was known in the firſt century, if not ſooner, and it is certain, I apprehend, that it was known in the ſecond.

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[*] Muratori Antiq. Vol. II. p. 393.

[†] Art. Miroir.

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* Philoſ. Tranſ. 1758, p. 602.

The Romans, before the time of the younger Pliny, not only uſed glaſs, inſtead of gold and ſilver, for drinking veſſels, but they knew how to glaze their windows with it, and they fixed it in the walls of their rooms to render their apartments more pleaſant. Now a piece of flat glaſs, fixed in the ſide of a room, is a ſort of looking-glaſs, and if the *ſtucco* into which it is fixed, be of a dark colour, it will not be a very bad one. And hence I think the Romans could not fail of having a ſort of *glaſs ſpecula* in uſe: but this, though admitted, does not come up to the point; the queſtion is, Whether they covered the poſterior ſurface of the glaſs with a metallic plate? It has been obſerved before, that the Romans knew how to make a paſte of gold and quickſilver, and it appears from Pliny alſo, that they knew how to beat gold into thin leaves, and to apply it in that ſtate both on wood and metal: now there is a paſſage in Pliny, from whence it may be collected, that the Romans began in his time to apply a coat of metal to glaſs ſpecula, and that this coat was of gold. The paſſage occurs in the very place where Pliny profeſſes to finiſh all he had to obſerve concerning ſpecula *. An opinion, ſays he, has lately been entertained, that the application of gold to the back part of a ſpeculum, renders the image better defined. It is hardly poſſible that any one ſhould be of opinion, that a plate of gold put *behind* a *metallic* ſpeculum, could have any effect in improving the reflected image; but ſuppoſing Pliny (whoſe tranſitions in writing are often abrupt) to have paſſed from the mention of *metallic*, to that of *glaſs ſpecula*, then the propriety of the obſervation relative to the improved ſtate of the image is very obvious. If we ſuppoſe the Romans in Pliny's age to have ſimply applied ſome black ſubſtance to the back ſurface of the glaſs, or even to have known how to put tin behind it, yet the obſervation of the image being rendered more diſtinct by means of gold, might have been made with more juſtice than is generally ſuppoſed; for *Buffon* is of opinion, that a looking-glaſs made with a covering of gold and quickſilver, would reflect more light than one made in the ordinary way with tin and quickſilver *; and hence

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* Atque ut *omnia* de ſpeculis peragantur hoc loco. Optima apud majores fuerant Brunduſina ſtanno et ære mixta. Prælata ſunt argentea. Primus fecit Praxiteles, magni Pompeii ætate. Nuper credi cæptum certiorem imaginem reddi auro appoſito averſis. Hiſt. Nat. L. XXXIII. S. XLV.

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* Ou pourroit trouver le moyen de faire un meilleur étamage, et je crois qu' on parviendroit en employant de l' or et du vif-argent. Hiſt. Nat. Buffon. Sup. Tom. I. p. 451.

Pliny's expreſſion, *certiorem imaginem reddi auro appoſito averſis*, will be accurately true.

Alexander Aphrodiſeus flouriſhed towards the end of the ſecond century, he wrote ſeveral works in Greek, and amongſt the reſt, two books of Problems, one of his problems is this[*]: Δια τι τα ὑελινα κατοπτρα λαμπουσι αγαν; Why are glaſs ſpecula ſo very reſplendent?

The only part of the anſwer which we are concerned with, is,

Οτι ενδοθεν αυτα χριουσι κασσιτερω.

Becauſe they beſmear the inſide of them with tin.

The Greek word which I have here rendered *beſmear*, does not clearly point out the manner in which the operation of fixing the tin upon the glaſs was performed. Pliny uſes a Latin word (*illitum*) of exactly the ſame import as this Greek one, when he ſpeaks of copper veſſels being tinned; and as in that operation, tin is melted and ſpread over the ſurface of the copper, I ſee no difficulty in ſuppoſing, that the tin may have been, in the time of Alexander Aphrodiſeus, melted and ſpread over the ſurface of the glaſs, when previouſly heated.

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[*] ΑΛΕΞΑΝΔΡΟΥ ΑΦΡΟΔΙΣΕΩΣ ιατρικα απορηματα και φυσικα προβληματα. Pariſiis, 1541.—If there be any doubt concerning the authenticity of theſe problems, I leave it to be diſcuſſed by the Critics.

Having carried up the invention of covering glaſs ſpecula with a metallic coating to the ſecond century, we may be the more ready to admit that the *Sydonians* poſſeſſed this art, before Pliny wrote his Natural Hiſtory: for in that work, he not only praiſes them for their former ingenuity in various glaſs manufactures, but he adds—and they had invented ſpecula alſo *.—Now there is ſome reaſon to think, that if the Sydonians had only invented the art of uſing a flat piece of glaſs as a ſpeculum, without knowing how to give it a metallic coating, on which its excellency chiefly depends, they would not have merited the mention which Pliny makes of them; for their looking-glaſſes muſt have been inferior to the metallic mirrors then in uſe at Rome. There ſeems to be but one objection of any conſequence to this concluſion,—had the method of giving a metallic covering

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* Aliud (vitrum) flatu figuratur, aliud torno teritur, aliud argenti modo cælatur, Sydone quondam iis officinis nobili, ſiquidem etiam ſpecula excogitaverat. Hiſt. Nat. L. XXXVI.

vering to plates of glaſs been known, at leaſt to the Romans, (for it might have been known in *Aſia* long before it was known in *Italy*) it ſeems probable, that the metallic ſpecula would have fallen into general diſuſe, much ſooner than there is cauſe to think they did; for it would have been much eaſier to make a looking-glaſs, than to poliſh a metallic mirror; and the image from the glaſs would have been ſuperior to that from the metal, and on both accounts the mirrors would have become unfaſhionable.

The firſt mode of fixing a coat of *tin* on a looking-glaſs, I ſuſpect to have been that of pouring the melted metal on the glaſs; and I have ſome reaſon, not now to be inſiſted on, to think, that this mode was not diſuſed in the fourteenth century.—*Baptiſta*

Porta lived in the fifteenth, and died towards the beginning of the ſixteenth century; he gives us a very accurate deſcription * of the manner in which looking-glaſſes were *then* ſilvered; it differs from that now in uſe only in this, that the tin-foil, when ſilvered, was taken up and gently *drawn* upon the glaſs. *J. Maurice Hoffman* publiſhed his *Acta Laboratorii Chemici* in 1719; he there ſpeaks † of a mixture of 1 part of tin with 3 of quickſilver, which ſometime ago, he ſays, was uſually applied to the back ſurfaces of looking-glaſſes; although the *Venetians* did *then* make looking-glaſſes by pouring quickſilver upon tin-foil placed on the back ſurface of the glaſs.—This mode of ſilvering the glaſs was not *then* invented by the *Venetians*, as appears from what Baptiſta Porta had advanced above two hundred years before; though the mode of ſilvering the tin-foil, when *laid* upon the glaſs, was an improvement on that preſcribed by Baptiſta Porta, juſt as the mode now in uſe, is a great improvement on that practiſed by the Venetians in the time of Hoffman.

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* Magia Nat. L. IV. C. XVIII.

† Pag. 245.

The men who are employed in ſilvering looking-glaſſes often become paralytic, as is the caſe alſo with thoſe who work in quickſilver mines; this is not to be wondered at, if we may credit Mr. Boyle, who aſſures us, that mercury has been ſeveral times found in the heads of artificers expoſed to its fumes*. In the Philoſophical Tranſactions*, there is an account of a man, who having ceaſed working in quickſilver for ſix months, had his body ſtill ſo impregnated with it, that by putting a piece of copper into his mouth, or rubbing it with his hands, it inſtantly acquired a ſilver colour. This, though a ſurpriſing, is not a fact of a ſingular nature; it is well known, that ſulphur, taken inwardly, will blacken ſilver which is carried in the pocket; and I have ſomewhere read of a man whoſe keys were ruſted in his pocket, from his having taken, for a long time, large quantities of diluted acid of vitriol. I remember having ſeen at Birmingham, a very ſtout man rendered paralytic in the ſpace of ſix months, by being employed in fixing an amalgam of gold and quickſilver on copper; he ſtood before the mouth of a ſmall oven ſtrongly heated, the mercury was converted into vapour, and that vapour was inhaled by him. A kind of chimney, I believe, has of late been opened at the farther ſide of the oven, into which the mercurial vapour is driven, and thus both the mercury is ſaved, and the health of the operator is attended to. The perſon I ſaw was very ſenſible of the cauſe of his diſorder, but had not courage to withſtand the temptation of high wages, which enabled him to continue in a ſtate of intoxication for three days in the week, inſtead of, what is the uſual practice, two.

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* Boyle's Works, Vol. III. p. 330.

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* 1665.

ESSAY VII.

Of the tranſmutability of Water into Earth.

SIR *Iſaac Newton* and Dr. *Bentley* met accidentally in London; and on Sir Iſaac's inquiring what philoſophical purſuits were carrying on at *Cambridge*, the Doctor replied —None — for when you go a hunting, Sir Iſaac, you kill all the game: you have left us nothing to purſue. Not ſo, ſaid the philoſopher, you may ſtart a variety of game in every buſh, if you will but take the trouble to beat for it. And ſo in truth it is; every object in nature affords occaſion for philoſophical experiment; and every experiment which is made, even with an expreſs view to any particular inveſtigation, incidentally ſuggeſts matter for new inquiry. But as in contemplating the civil hiſtory of the world, we are under the neceſſity of being contented with abridgments of its ſeveral parts, with remembering the great revolutions which have in fact taken place; without minutely exploring all the ſecret cauſes, all the fortuitous circumſtances by which they were effected; ſo in the preſent ſtate of experimental philoſophy, we muſt reſt ſatisfied, as to many ſubjects, with knowing the general concluſions,

cluſions, without attempting to ſcrutinize all the particular experiments, on which they are founded. All the works of the writers of *Greece* and *Rome*, which have come down to our time, do not equal a third part of the bulk of thoſe which have been publiſhed by individuals, and by the ſeveral philoſophical ſocieties of Europe on experimental philoſophy alone, ſince the middle of the laſt century: nor does the nature of things preſcribe any limit to human induſtry, exerted in the proſecution of ſuch inquiries. There is not an animal, or a vegetable ſubſtance that we feed on; nor a ſaline ſubſtance that we taſte; nor a beverage that we drink; nor the air that we breathe; nor a metal that we handle; nor a ſtone that we tread on, but what may furniſh matter for an infinity of experiments. What a ſource of natural knowledge is water alone? Who can underſtand all the properties that belong to it as a body, that is fluid in a certain degree of heat; ſolid in a leſs; and convertible into an elaſtic vapour of incredible force in a greater; as capable of diſſolving all kinds of ſalts; as abſorbing and detaining in its ſubſtance the air of the atmoſphere; as being itſelf abſorbed by, and ſuſpended in the air; as conſtituting the principal part not only of blood, urine, milk, wines, oils, ſpirits, and all fluid bodies; but as entering, in a large proportion, into the conſtitution of the ſolid parts of all animal, and vegetable, and of many mineral ſubſtances; as being reſolvable, according to the moſt recent diſcoveries,

ries, into two different ſorts of air; and as being tranſmutable into earth? It is concerning the experiments which have been made relative to this laſt property, that I mean, in this Eſſay, to give a brief hiſtorical account. Men advance very ſlowly in the attainment of phyſical knowledge: the trouble of making experiments is great, but ſhort relations of their reſults cannot fail of being entertaining to minds imbued with any taſte for ſuch kind of inveſtigation; and there are few queſtions of greater importance in the eſtimation of ſpeculative philoſophers, than that which reſpects the tranſmutability of water into earth. If but one particle of water can by any means be changed into a particle of earth, the whole doctrine of the *Peripatetic* ſect, concerning the *Elements* of things, will be utterly ſubverted: the diverſities of the bodies ſubſiſting in the univerſe, will no longer be attributed to the different combinations of *earth*, *air*, *fire*, and *water*, as diſtinct, uncompounded, immutable principles; but to the different magnitudes, figures, and arrangements of particles of matter of the ſame kind.

Thoſe who maintain the tranſmutability of water into earth, ſupport their opinion, principally, by arguments deduced from the reſult of two very different kinds of experiments. In the one they appeal to the mechaniſm of nature, and contend, that vegetation, however inexplicable it may be in its manner of operation, is certain in its effect, and invariably changes water into earth. In the other, they have recourſe to the aſſiſtance of art, and by ſo ſimple a proceſs as that of diſtillation, indefinitely repeated, they hold it poſſible to exhibit any determinate quantity of water under the form of a white, impalpable, opake, inſipid powder.

When the vaſt genius of *Bacon* had rendered the authority of *Ariſtotle* leſs reſpectable, and men's minds were every where alarmed with a ſuſpicion, that Truth and *He* might poſſibly be on different ſides; ſeveral appearances in nature, which had either eſcaped the obſervation, or, from ſeeming repugnant to the eſtabliſhed maxims of the Schools, had been deemed unworthy the animadverſion of philoſophers, began to be examined with a minute attention: we have an inſtance of the truth of this obſervation in the ſubject before us.

The pureſt water could never have been wholly diſtilled in glaſs veſſels, but the operator might have had an opportunity of obſerving a thin pellicle of earth, tarniſhing the tranſparency, and adhering to the bottom of the veſſel employed in the proceſs. This appearance is conſtant, it preſents itſelf not only when the water is firſt diſtilled, but after it has been purged, as much as poſſible, from every foreign impurity by reiterated diſtillation. Yet notwithſtanding the invariable uniformity of this phenomenon, I know not whether it was noticed by any one before *Borrichius*, as furniſhing an incontrovertible proof of the tranſmutability of water into earth. Why, ſays he, ſhould we dwell upon the poſſibility of chemical principles being converted into one another, when the very elements of Ariſtotle are not exempt from change? He then proceeds to obſerve, that water, how frequently ſoever he had diſtilled it from freſh glaſs veſſels, ſtill left at the end of each ſucceſſive operation, a ſlender coating of earth ſticking to the ſide of the veſſel, and he attributes the production of this earth, not to any extraneous impurity accidentally mixed with, and obſtinately adhering to the water, but to a tranſmutation of the water into a true, firm, fixed, inſipid earth *. In ſaying that *Borrichius*

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* Et quid chemica moramur? Ipſa *Ariſtotelis* elementa non ſunt ab his immunia mutationibus.

chius was the *firſt* perſon who made this obſervation, I may, perhaps, be guilty of ſome inaccuracy. The *imprimatur* for Borrichius' book, here referred to, is dated at *Copenhagen* in 1673: now it is certain, that *Boyle's* treatiſe concerning the Origin of Qua-

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tationibus. Enimvero aqua, etiam limpidiſſima, et, ſi placet, vel decies per deſtillationes ab omni fœce libera in veram, firmam, fixam, et inſipidam terram mutabitur, ſi eandem iterum, iterumque frequentiſſimè ex recentibus ſemper vaſis vitreis lente deſtillando evoces; quavis enim vice tenella quædam cuticula terrea, ſed elegans, ex aquâ illa enata ſuperficiei interiori vitri agglutinabitur, quod frequentibus experimentis didici; cumque illud ipſum ante hos X annos narrarem Cl. Oxonienſis Academiæ Medico Edmundo Dickenſotino, idem ſibi compertum centeſimâ deſtillatione aſſeruit. Hermetis Ægypt. et Chem. Sapien. per Ol. Borrichium, p. 397.

Qualities and Forms, in which the tranſmutation of water into earth by diſtillation, is diſtinctly mentioned, was publiſhed at Oxford in 1666; yet as Borrichius had ſpoken of this experiment to a phyſician at Oxford ten years before he publiſhed his book, and as it is very probable, that Boyle was unacquainted with this experiment when he firſt publiſhed his Sceptical Chemiſt in 1661, Borrichius may, perhaps, be properly enough eſteemed prior to Boyle in the invention and application, though poſterior to him in the publication of the experiment.

Boyle, however, examined the matter with greater preciſion than Borrichius had done. It his treatiſe concerning the Origin of Qualities and Forms, he acquaints us with the firſt occaſion of his making the experiment [*]. A gentleman who, in order to diſcover the grand *arcanum*, had employed, among other things, great quantities of purified rain water, complained to him, that inſtead of obtaining what he looked for, he met with a great deal of a whitiſh excrementitious matter, which he knew not what to make of. The great plenty and ſome peculiar qualities of this matter, which had ſo much perplexed the old chemiſt, ſuggeſted to Mr. Boyle a ſuſpicion, that it was not owing to any accidental foulneſs of the water, and put him upon trying,—whether water, which had been previouſly purified by diſtillation, would not, by being re-diſtilled, leave, at the end of the operation, a portion of earth. The reſult of his experiment confirmed him in his conjecture, that the earthy powder obtained by diſtilling rain water, might be a tranſmutation of ſome parts of the water into earth: and he was much ſtrengthened in this belief by converſing with a phyſician (probably the ſame perſon mentioned by *Borrichius*) who aſſured him, that he had frequently found a white earth in diſtilled rain water, even after he had diſtilled the ſame numerical liquor a great many times.

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[*] Boyle's Works, fol. Vol. II. p. 519.

Boyle ſeems to have been very cautious in admitting this tranſmutation, the oddneſs of it he owns ſtill kept him in ſuſpenſe; and it was not without much delight, that he was informed by an ingenious perſon of unſuſpected credit, who, with a medical view, had been long working

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upon rain water, that water which he had diſtilled near *two hundred times*, ſtill afforded a white earth; and that more *copiouſly*, at leaſt more conſpicuouſly in the *latter* diſtillations, than in the *former*. This gentleman out of one ounce of diſtilled rain water, had obtained, by reiterated diſtillation, near three quarters of an ounce, if not more, of earth. The phyſician *Dickenſon*, mentioned by Borrichius, was probably the perſon alluded to by Boyle in this account; for *Houghton* ſays in his Collection, "I have heard that Dr. Dickenſon has turned eighteenth parts of water out of twenty parts into earth, only by repeated diſtillation." Yet, even this account, concluſive as one might think it, could not extort from Boyle a full conviction of the poſſibility of tranſmuting water into earth by diſtillation; he calls the hypotheſis a bold conjecture, and expreſsly mentions ſome ſcruples which ſtill remained with him. Two of theſe ſcruples are worthy of particular notice, inaſmuch as they contain the two principal objections, which have been made, by ſubſequent philoſophers, to the doctrine which he endeavoured to eſtabliſh. The firſt reſpects the *veſſels* in which the experiment had been uſually tried; the ſecond has relation to the water itſelf. — "It were fit to know," ſays he, "whether the glaſs body, wherein all the diſtillations are made, do loſe of its weight, any thing near ſo much as the obtained powder amounts to."—And again, "I could wiſh that it were demonſtrably determined, what is on all hands taken for granted, that diſtilled rain water is a perfectly homogeneous body *."

It does not appear that Boyle was ever fully ſatisfied with reſpect to theſe doubts, he reſumes indeed the ſubject in a tract, intitled, Experiments and Notes about the produceableneſs of Chemical Principles, publiſhed at Oxford in 1680, and mentions a new trial which he had made; yet he there repeats his ſcruple concerning the homogeneity of water, and though upon the whole he appears willing to believe, that water might be tranſmuted into earth by diſtillation, and the nature of his ſubject led him to make the moſt of ſo remarkable an experiment, yet he candidly owns, that ſome of his experiments afforded ſtrong probabilities, rather than concluſive proofs.

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* Id. p. 522.

Notwithſtanding the diffidence with which Boyle himſelf propoſed his opinion concerning the tranſmutability of water into earth, it appears to have been very generally admitted from his time to *Boerhaave's*; and even *Newton*[*] ſo far believed it, as to think it poſſible that water might be made red hot[†].

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[*] "Water by frequent diſtillations changes into fixed earth, as Mr. Boyle has tried, and then this earth being enabled to endure a ſufficient heat, ſhines by heat like other bodies." Newton's Optic. Quæ.

[†] Another method is mentioned, by which water may be made red-hot. If a ſpoonful of water be thrown upon the ſurface of a large quantity of melted glaſs, in a glaſs-houſe furnace, it will aſſume a globular form, and appear to roll about on the ſurface of the glaſs as if it was a melted metal; it will make no exploſion, but becoming red-hot, it will by

Boerhaave oppoſed the general perſuaſion ||; he did not deny, that earth was always found at the bottom of the glaſs veſſel in which water had been diſtilled, nor that the quantity of

little and little be diminiſhed in bulk, and at length be totally diſſipated *. The author of this obſervation attempts to explain the phenomenon; M. *Boſc d'Antic* †, thinks the explanation improper; but he allows the exiſtence of the little globes, and ſays they are hollow, and of an earthy nature: when this appearance has been more fully examined, it is probable that it will be conſidered as an argument in ſupport of the tranſmutability of water into earth; though Dr. Prieſtley has remarked, "that *water* after being heated red-hot, was ſtill water, there being no change in its ſenſible properties ‡."

|| Boerh. Chem. Vol. I. p. 627.

* Rozier's Journ. Jan. 1778.

† Ouvres de M. B. d'Antic, Vol. II. p. 276.

‡ Phil. Tranſ. 1785, p. 291.

of earth was conſtantly increaſing with the increaſe of the number of diſtillations which the water had undergone; but he thought that this earth did not proceed from the water itſelf, but from the duſt which is always floating in the atmoſphere, eſpecially in the atmoſphere of elaboratories. It could not be imagined, that the atmoſphere included in the veſſels uſed for diſtillation, could furniſh any conſiderable quantity of duſt in one operation, yet being renewed by the opening of the veſſels, as frequently as the diſtillation was repeated, it ſeemed to him to be a cauſe fully adequate to the effect.

It is a matter of wonder, that Boerhaave ſhould aſſign ſuch a reaſon for this phenomenon, conſidering the reſult of an experimet mentioned by

Boyle, in which he expoſed the ſame water, in the ſame veſſel *hermetically* ſealed, to a *digeſtive* heat for above a year*: after it had continued a good while, little concretions, heavier than the water, began to be formed, and he expreſsly remarks, that the longer the glaſs was kept in the digeſtive furnace, the more of this fine terreſtrial ſubſtance was produced; an event impoſſible to be explained from the duſt floating in the atmoſphere, as the veſſel, by being hermetically ſealed, effectually excluded the minuteſt particle of duſt from coming in contact with the water.

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* When the neck or hollow ſtem of a glaſs veſſel is ſo ſoftened by fire, that the two ſides of it may be pinched together, the veſſel is ſaid to be *hermetically* ſealed; thus the upper end of the tube of a mercurial thermometer, is hermetically ſealed.—A *digeſtive* heat, is, in general, any degree of heat above that in which water freezes, and below that in which it boils: but 150° of Fahrenheit's thermometer is commonly called a digeſtive heat. The operation called *digeſtion*, conſiſts in expoſing liquids, or liquids and ſolids, to a digeſtive heat in ſuitable veſſels for a due time.

Though this experiment, properly conſidered, was certainly concluſive againſt Boerhaave's hypotheſis, yet *Marggraf* undertook to ſhew its inſufficiency in another manner *. He contrived a retort and a receiver of the ſame piece of glaſs, and through an hole in the receiver, which he afterwards cloſed with a glaſs ſtopple, he poured an ounce of water which had been carefully diſtilled thirteen times; this water he re-diſtilled, without ſuffering any air to enter into the retort, thirty times more, and obſerved that the water, which was at firſt exceedingly tranſparent, became more and more troubled by the admixture of a fine white earth, as the number of diſtillations was increaſed. The refutation of Boerhaave's hypotheſis, was not the only point which Marggraf had in view in making his experiments on water; he was deſirous alſo of obviating the objections of thoſe who were diſpoſed to attribute the origin of the earth to an abraſion of the parts of the glaſs, rather than to a tranſmutation of the particles of water. In order to this he has not only remarked, that the veſſels in which he had diſtilled water ſo frequently, were, as far as microſcopes could inform him, as perfectly poliſhed as when new, and that they were of the very beſt ſort of glaſs, in which ſpirit of ſalt might be kept for many years without its injuring them, but he has ſhewn that fire is not eſſential to the production of the effect; an earth being ſeparable from diſtilled water by the ſimple action of the ſun evaporating the water, and even without any heat by a long continued agitation. Sir Iſaac Newton was of opinion, that the water upon the ſurface of the earth was daily diminiſhed by vegetation, and if we may rely upon theſe experiments of Marggraf, we ſee that there are two other cauſes which have a tendency to produce the ſame effect; for the water of the ocean is inceſſantly raiſed into the atmoſphere by evaporation, and agitated by the action of the winds and tides; and if it be by both theſe cauſes converted in part into earth, we may admit that the *Caſpian* ſea is leſs now than it was formerly, and that the *Mediterranean* ſea has retired from the coaſts of France, Spain, Portugal, and Italy, without having recourſe, with *Buffon*, to the ſinking of immenſe caverns within the bowels of the earth, into which the ſea has from time to time retired. With reſpect, however, to this ſuppoſed diminution of the ſea, it may be obſerved, that it is well underſtood that the ſea has encroached upon the ſhore in ſome places, and deſerted it in other; but I do not know whether geographers are able, on ſolid grounds, to ſay,—whether the quantity of land throughout the whole globe, is, or is not, the ſame now that it was 4000 years ago.

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* Opuſ. Chy. de M. Marggraf, Vol. II. p. 176.

M. *Eller* had, in 1746, obtained earth from water by triturating it in a glaſs mortar*; and *Wallerius*, in 1760, with a view of removing the ſuſpicions of *Pott*, who thought the earth proceeded from the mortar itſelf, varied in ſome meaſure Eller's experiment, by triturating water in mortars of iron and bronze†. The old proverb—*gutta cavet lapidem*—would render experiments of this kind very ſuſpicious, if the authors did not aſſure us, that the earths obtained by trituration, were not of the nature of the veſſels in which the experiments were made: and Marggraf alſo affirms, that the earth which he procured from water by repeated diſtillation,

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* Mem. de l'Acad. de Berlin, 1746.

† Recueil des Mem. de Chy. Vol. II. p. 542.

ſtillation, had properties very different from thoſe of pounded glaſs.

In oppoſition to the opinion of theſe philoſophers, M. *Le Roi* has undertaken to ſhew *, that the very experiments produced by Marggraf and others, in proof of the tranſmutability of water into earth, do not, though they be admitted in their full extent, ſufficiently eſtabliſh the fact. His reaſoning turns chiefly upon the ſecond of Boyle's ſcruples before mentioned: he apprehends that rain water ought not to be eſteemed an homogeneous fluid, but that it contains an earth ſubtilely mixed with, or diſſolved in the water, from which it cannot be ſeparated by any number of diſtillations, however great. — Marggraf himſelf was quite aware of this difficulty; he ſays he ſuſpected, that water which had been diſtilled but once by the retort, might probably contain ſome portion of attenuated earth which had riſen in the diſtillation, but which did not belong to the water; and he therefore diſtilled the water, on which he made his experiment, thirteen times, and ſix of them with the gentle heat of boiling water. That rain water, collected with every poſſible precaution, contains not only a portion of earth, but ſmall quantities alſo of the acids of nitre and ſea ſalt, is proved beyond a doubt by the experiments of Marggraf himſelf; the only point in diſpute is, whether theſe heterogeneous admixtures can be ſeparated from water by reiterated diſtillation or not? M. Le Roi thinks, that they cannot; according to him the vapour of water, which riſes in diſtillation, carries with it a portion of the impurities contained in the water, This objection may recur for ever, let the number of diſtillations be what they may, nothing ſhort of a complete tranſmutation of a definite quantity of water can wholly obviate it.

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* Hiſt. de l'Acad. des Scien. a Par. 1767.

The experiment before mentioned, in which Boyle's friend obtained from an ounce of water, near three quarters of an ounce of earth by 200 diſtillations, approaches the neareſt of any that has ever been made to a complete tranſmutation: but this experiment has of late been conſidered by M. Le Roi and others, as meriting no manner of attention; principally becauſe it does not correſpond with ſimilar experiments of more modern chemiſts, eſpecially of Marggraf, whoſe accuracy is above all queſtion. He could not obtain from 72 ounces of pure rain water, by 13 diſtillations, above 12 grains of earth; a quantity very inconſiderable, in compariſon of what it ought to have been, in order to have agreed with the quantity obtained by Boyle's friend.

I have no intention to enter into a formal defence of this famous experiment mentioned by Boyle; it may be obſerved, however, that neither Marggraf, nor any other chemiſt, ever diſtilled the ſame identical water ſo frequently, as the author of this experiment did*: his relation of it then, it is evident, is not contradicted from obſervation, but from inference, and the inference has been founded on a principle, rather taken for granted, than proved. The principle is this, — that if any number of diſtillations, ſuppoſe ten, yield a certain portion of earth, twenty times that number, or 200 diſtillations, would yield twenty times as much, at leaſt not more, earth. — Now there are ſome reaſons to believe, that this principle is not true; for not to inſiſt on what Boyle, however, intimates, of the earth being more plentifully

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* This obſervation is not, I believe, true; Boer-

Boerhaave is ſaid to have diſtilled the ſame water 500 times; I have not ſeen all the works of Boerhaave, nor does the author, who makes this remark concerning him, refer to the particular part of his works where the fact is mentioned. Fourcroy's Chem, Eng. Tranſ. Vol. I. p. 115.

tiſully afforded in the latter diſtillation, than in the former, Marggraf himſelf has made two obſervations, which, when taken together, ſeem to prove the ſame thing. He affirms, and Wallerius agrees with him, that more earth is ſeparated when water is kept boiling with a *ſtrong* than with a *gentle* heat; and he obſerves alſo, and eſteems it a fact altogether ſingular, that water which has been *often* diſtilled, requires for its elevation, eſpecially towards the end of the operation, when but a ſmall quantity remains in the retort, a degree of heat exceedingly ſtrong, when compared with that which any other water requires *. From theſe obſervations I would argue thus; if it be true, that *more* earth is ſeparated when water is diſtilled with a *ſtrong* than with a *gentle* heat; and if it be true alſo, that the *degree* of heat neceſſary to diſtil water is *ſtronger*, as the number of diſtillations it has previouſly undergone is *greater*, will it not be a juſt conſequence, that the quantity of earth ſeparable by a ſingle diſtillation, or by any definite num-

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* — pendant la diſtillation, il faut entretenir continuellement l'eau que la retorte con-

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contient, dans une *forte* coction. Ou trouvera que, par ce moyen, il ſe ſépare toutes les ſois plus de terre de l' eau, que quand la diſtillation ſe fait lentement.—Ou doit remarquer comme quelque choſe de tout-a-fait particulier, que plus ſouvent une ſemblable eau eſt diſtillée, et plus l' operation devient difficile, ſur-tout a la fin, quand une partie de la liqueur a diſtillé; car alors le reſidu demande un dégré de fu *trés-véhément* en comparaiſon de toute autre eau. Opuſ. de Marg. Vol. II. p. 193.

number of diſtillations, will be greater as the number of previous diſtillations has been greater? If this be admitted, it eaſily follows, that the quantity of earth ſeparable by 200 diſtillations, cannot be properly calculated by the rule of proportion, from what actually has been ſeparated by 13, or any other number of diſtillations ſo greatly ſhort of 200. Moreover, this experiment is not deſtitute of a kind of collateral proof; for Wallerius has obſerved, that the quantity of earth which he obtained by triturating a certain quantity of water in a glaſs mortar for four days, agrees pretty exactly with the quantity procured by the 200 diſtillations mentioned by Boyle.

M. *Lavoiſier* * rejects the notion of

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* Hiſt. de l'Acad. des Scien. a Paris, 1770.

the tranſmutability of water into earth by diſtillation, as well as M. *Le Roi*; but he rejects it upon different principles: he has endeavoured to remove the other ſcruple mentioned by Boyle, and has done, what it is ſurpriſing no chemiſt ever thought of doing before his time, conſidering that the hint had been given above 100 years ago; he has weighed the glaſs veſſel in which the operation was performed, and has found that its weight after the operation, is leſs than it was before the operation; and this loſs of weight he attributes to the abraſion, or ſolution of the parts of the glaſs. M. Lavoiſier's experiment reſembles that of Boyle before mentioned, in which water was expoſed to a digeſting heat, in a veſſel hermetically ſealed; but he conducted ed it with more accuracy. I have three reaſons for heſitating concerning Mr. Lavoiſier's opinion, which refers the earth found in the veſſel after the diſtillation of water, to the abraſion of the glaſs. In the firſt place, the earth procured by diſtillation, is not of the ſame kind, has not the ſame chemical properties, as pounded glaſs has. Secondly, Mr. Lavoiſier did obtain 3 grains of earth, above the loſs of weight which his veſſel had ſuſtained, and this quantity may, perhaps, be as much as ought to be expected from ſuch an experiment, ſuppoſing that water is convertible into earth; for the heat he made uſe of in the operation was ſmall. And laſtly, I have ſlowly diſtilled water in a ſilver retort, and afterwards evaporated the diſtilled water on a poliſhed ſilver plate, there remained on the plate a ſmall pellicle of earth. When a drop of water, ariſing from the vapour condenſed in the top of a ſilver tea vaſe, happens to fall upon the body of the vaſe, it is preſently evaporated; but it always tarniſhes the ſpot on which it has fallen. I am aware it may be contended, that the earthy pellicle in both theſe caſes, may be attributed to a precipitation of the duſt floating in the atmoſphere, or to an attenuated earth, which is mixed with the water and carried up by the vapour. On the whole, the poſſibility of converting water into earth by diſtillation, remains, I think, ſtill an undecided problem; M. Lavoiſier's experiment ſtaggers the confidence I had repoſed in the concluſions of Margraf,

graf, but it muſt be repeated with ſucceſs before it will utterly ſubvert it.

With reſpect to the converſion of water into earth by *vegetation*, many philoſophers of great eminence have admitted it without ſcruple. *Van Helmont* * derived not only vegetables, but all ſubſtances whatever from water, and boaſted that he was the firſt author of that hypotheſis. It may be obſerved, however, that in the earlieſt ſyſtems of philoſophy, we have the plaineſt alluſions to this doctrine, and to the *Moſaic* account of the creation. Thus *Beroſus*, the famous prieſt of Babylon, held *water* and *darkneſs*; (*dark-*

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* De Lithiaſi, C. I. S. IV.—Aſt ad me uſque neſcitum fuit, cuncta corpora, quæ miſta creduntur, materialiter duntaxat ex ſola aqua eſſe, nullo excepto.

(*darkneſs* was upon the face of the *deep*, Gen. i. 2.), the Phenicians *darkneſs*, a *choas*, and *wind*; the Perſians *light*, to have been the firſt principles from which all things proceeded. The moſt ancient *Greeks*, if the opinion of *Homer* be of any weight in this matter, derived the origin of all things from *water*; this doctrine was followed about 300 years afterwards by *Thales* of *Miletus*; who, travelling into Egypt and converſing, as *Diogenes Laertius* tells us, with the prieſts of that country, heard from them, probably, ſome tradition concerning the creation; by which means he improved much upon the poet, teaching, as *Cicero* obſerves, *Deum eam mentem eſſe, qui ex aqua omnia fingeret.*

Val Helmont * produced a ſingular experiment in ſupport of his opinion, that water became earth by vegetation. He took an earthen veſſel and put into it 200 pounds weight of earth, which had been previouſly dried in an oven; he wetted the earth with rain water, and planted in it the trunk of a willow which weighed five pounds. In the ſpace of five years, the willow weighed 169 pounds 3 ounces: the earth was watered, when it was neceſſary, during the whole of the time with either rain or diſtilled water; the veſſel was ſpacious, and was ſunk into the ground, and, to prevent any duſt from falling into it, its mouth was covered with tin plates, which were pierced with many holes. No account was taken of the leaves which fell in four ſucceſſive autumns. The earth was taken out of the veſſel,

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* Opera omn. p. 105.

ſel, dried, and weighed at the expiration of the five years, and it had loſt only about 2 ounces, ſo that 164 pounds of wood, of bark, and of roots, of which the tree conſiſted, had ariſen from the water. I have related this experiment at full length, as it is the firſt of the kind which was made, and is as concluſive as any of thoſe which have been made ſince by *Boyle*, *Du Hamel*, *Eller*, and others. *Beccher* admits the fact as ſtated by *Van Helmont*, but he objects to the concluſion; water, ſays he, will never become earth, except ſo far as it carries ſome earthy particles along with it*. M. *Le Roi* adopts the ſame notion, when he attributes the increaſe in the weight of the willow, to the earthy and ſaline particles from which water cannot be freed, even by diſtillation. It is, moreover, well known, that plants ſuck in nutriment from the air by their leaves, and

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* —nec ſufficit ſolis verbis omnium rerum originem aquæ tribuere, aut experimentum Helmontii in vegetatione arboris, quod Robertus

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bertus Boyle in chemiſta ſceptico citat. Aqua profecto nunquam terra fiet niſi in quantum corpuſcula terrea ſecum vehat. Beccher Phy. Sub. p. 87.—Calcined plaſterſtone, and the materials uſed in making earthen ware, abſorb much water, and are increaſed in weight, as vegetables are by abſorbing water in vegetation; and ſome are of opinion, that water, by being united to what is called (from the ſubſtance which yields it by a peculiar proceſs) *ſparry acid*, may be changed into a flinty earth; but in all theſe, and in other ſimilar caſes, it may be queſtioned, whether the particles of water may not be *wholly* diſunited from the ſubſtances with which they are combined, and again exhibited under the form of water.

and this nutriment is not a pure water, ſince the pureſt atmoſpherical water contains both *oily*, *ſaline*, and *earthy* principles, if we may truſt the analyſes which have been made of it. In addition to this remark, I would obſerve, that though the willow gained an increaſe of 164 pounds in weight, yet a very ſmall portion of that weight was earth; ſince much the greateſt part of all vegetables, and eſpecially of ſucculent ones, conſiſts of water and air. I cut a leaf from the *mitre aloe*, it weighed 1644 grains; it was cut into ſlices, and expoſed to the heat of the atmoſphere in September; in 15 days it had loſt 1558 grains: I then burned it to a black aſh, it weighed in that ſtate 26 grains, and being burned to a white aſh, it weighed only 16 grains, which were compoſed only in part of earth; for they contained, though I omitted to examine them, a portion of fixed alkaline ſalt. A freſh *pumpkin*, which weighed 200 ounces, being cut into ſlices and dried in the ſun, loſt in nine days 190 ounces of its weight; the remaining 10 ounces being reduced to aſhes, did not yield one ounce of earth. Had Van Helmont reduced his willow to aſhes, I think it would not have yielded one pound of earth; this ſmall quantity of earth, added to the uncertainty there is as to the earth, wherein the willow was planted, being equally free from moiſture when it was weighed, before and after the willow had acquired its increaſe, renders the concluſion which is drawn from the experiment wholly queſtionable.

Count Gyllenberg *, in order to prove that *vegetables derive all their conſtituent parts from water, even their oils and ſalts, as well as their earthy particles*, makes the following obſervation. — " Four thouſand different plants can grow in twenty pounds weight of earth, and in each of them ſhall be found a different *oil* and a different *ſalt*. Let us ſuppoſe theſe plants to be chemically analized, near an *ounce of oil and ſalt* will be found in each. If this *oil* and this *ſalt* had proceeded from the earth, there muſt have been in that earth four thouſand ounces, or 250 pounds of *oil* and *ſalt*, whereas in fact there was not a grain of either of them in it." This obſervation does not prove, that ſimple water is converted into *earth*, or *ſalt*, or *oil* by vegetation; it merely ſhews, that plants by vegetating acquire ſuch an increaſe of weight, as cannot be derived from the earth in which they grew, and become bodies, whoſe conſtituent parts are different from both earth and water: but it neglects the conſideration of two ſubſtances, as neceſſary to vegetation as either earth or water—*light* and *air*. The *air* is a fluid whoſe conſtituent parts are not yet fully aſcertained; beſides water, there are reaſons to think that it contains an oily and a ſaline principle; and as to *light*, opticians have diſcovered not only that the ſame ray of it has different properties on its different ſides, but that it is by no means an homogeneous fluid, though no experiments have yet ſufficiently ſhewn, whether that fluid be a ſaline or phlogiſtic ſubſtance, or both. The rays of the ſun ſeem to be acted upon by every body in nature, and they may be capable of being combined with air, or water, or earth; and in that ſtate of combination they may enter as conſtituent parts into vegetables, &c. form airs, ſalts, and oils of various kinds. There may be an igneous and elaſtic fluid, as well as an aerial one univerſally diſperſed, and on which the fluidity of the air itſelf may depend; and this fluid, being imbibed by vegetables, may be a principal component part of them, and being reſtored to its fluidity by combuſtion, fermentation, and other cauſes, it may produce heat or flame, according to the circumſtances under which it endeavours to diſcharge itſelf. There is a curious experiment which will illuſtrate the efficacy of air and light in promoting vegetation.

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* Count Gyllenberg's Elements of Agriculture, tranſlated by Mills, p. 72.—— This work is attributed by Mr. Mills to Count Gyllenberg, by the French tranſlator to Walkerius; ſee the Ed. quoted in Vol. II. p. 76.

Mr. Eller took a large quantity of water which had been twice diſtilled, and having filled a cylindrical glaſs veſſel with it, he bound a ſheet of paper over the mouth of the veſſel, and ſet it in the ſun in the middle of ſummer for ſeveral weeks. He ſoon obſerved that the water began to be troubled, that it emitted ſmall bubbles, that its ſurface became ſomewhat frothy, and that the bottom of the veſſel was covered with a *green matter*. He afterwards diſtilled the water, and from the laſt portion of it, containing the green matter, he obtained an acid and an oil, and, though he does not mention it, there remained, probably, a portion of earth. I remember having ſeen a glaſs tube, which, after having been hermetically ſealed and nearly filled with water, had been left for ſome months on a table on which the ſun occaſionally ſhone, that ſide of the tube on which the rays of the ſun had fallen, was covered with *green matter*, whilſt the other ſide was free from it. Dr. Prieſtley, with his accuſtomed ingenuity, has inveſtigated the nature of the green matter which is thus formed, and ſhewn that it is a vegetable, whoſe ſeeds are conſtantly floating in the atmoſphere, and that *light* is abſolutely requiſite to its production, mere heat not being ſufficient for the purpoſe; but that light itſelf will not produce it in water which has no communication with the air; probably becauſe in that caſe the water is deprived of the ſeeds from which the vegetable ſprings, and hence we may infer, that the action of the ſun's light is not alone ſufficient to generate ſalts and oils in water, though it be inſtrumental in enabling the ſeed of the vegetable to expand itſelf into the form of a plant. The vegetable thus formed, certainly contains more *acid*, more *oil*, and more *earth*, than exiſted in the ſeed from whence it ſprung, but it would be a raſh concluſion to ſay, that ſimple water has been converted into any of theſe ſubſtances, though it ſeems to be a juſt one to ſay, that either the water, or the air in the water, or the ſolar light, have jointly or ſeverally been changed into them. Is it poſſible ſo far to purify a portion of atmoſpherical air from the ſmall ſeeds of vegetables, that diſtilled water, though in contact with this purified air, and expoſed to the action of the ſolar rays, ſhall not produce any green matter, or undergo ſuch a change, as to yield by diſtillation either a ſaline or an oily principle? —I have now given an account of the moſt noted arguments which have been brought in ſupport of, or in oppoſition to the doctrine of the tranſmutation of water into earth, and I am forced to conclude, from this view of the ſubject, that the queſtion is not clearly decided either way: as to my own opinion, I beg leave to ſay, that I am rather diſpoſed to believe that water is converted into earth, though I own that no experiment has yet been produced, to which reaſonable objections may not be made. The point I am ſenſible cannot be decided by authority; yet I will put an end to the diſquiſition by mentioning the opinion of Newton. — *Vegetabilia omnia ex liquoribus omninò creſcunt, dein magna ex parte in terram aridam per putrefactionem abeunt, et limus ex liquoribus putrefactis perpetuò decidit. Hinc moles terræ aridæ indies augetur; et liquores, niſi aliunde augmentum ſumerent, perpetuo decreſcere deberent et tandem deficere*[*].

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[*] Newtoni Oper. Vol. III. p. 157. Ed. Horſley.—Buffon, another philoſopher of no ſmall eminence, is of opinion, that the elements may be changed into each other, and that water may even become air. "Comme

je ſuis *très perſuadé* que toute la matiére eſt convertible, et que les quatre elemens peuvent ſe transformer, je ſerois porté a croire, que l'eau peut ſe transformer en air lorſqu' elle eſt aſſez rarifié pour s'elever en vapeurs." Suppl. Vol. I. p. 100.

ESSAY VIII.

Of Weſtmoreland Slate, and ſome other Sorts of Stones.

WE have in the mountainous parts of *Weſtmoreland* various ſorts of ſlate; all of which are uſed by the inhabitants of that county for covering the roofs of their buildings; and the beſt of them are either carried by ſea to *London*, *Liverpool*, *Hull*, and *Lynn*, or by land into the biſhoprick of *Durham*, *Cumberland*, *Northumberland*, and *Lancaſhire*. The different ſorts of ſlate are diſtinguiſhed from each other by the fineneſs of their grain, by the thickneſs into which they are ſplit, by their colour, and by their weight. The moſt general colour is blue; there are many ſhades of it, from a very pale to a deep blue. The blue of ſome ſlates has a greeniſh caſt, this is very obſervable after a ſhower in a building which has been recently ſlated, if any of the greeniſh ſlates happen to have been uſed along with the blue. We have alſo a purple ſlate, and one which is nearly black, or at leaſt is ſo dark, that it is uſed for writing on. With reſpect to the comparative weights of different ſorts of ſlate, the following table, which was made with ſufficient care, will give the reader ſome notion of the ſubject.

Weight of a cubic foot of different ſorts of ſlate.

	Ounces.
Purple ſlate, Kentmere near Kendale	2797
Pale blue, Coniſton Water Head -	2791
Dark blue, Troutbeck - -	2781
Pale blue, Throng Crag -	2780
Pale blue, White Moſs - -	2779
Deep blue, Old Cauldron -	2778
Pale blue, greeniſh, near Ambleſide	2768
Pale blue, Ingleton, Yorkſhire -	2767
Dark, writing ſlate, Banneſdale -	2765
Blackiſh, uſed for flooring, Head of Winander Mere -	2758
Deep blue, Longdale - -	2752
Greeniſh blue, Kentmere -	2750
Blackiſh, Cartmel, Lancaſhire -	2740
Very pale blue, fine grained Ambleſide	2732
Medium weight of a cubic foot	2767

I have not in this table included all the varieties of ſlate which may be met with in Weſtmoreland; but it is not probable, that thoſe which I have omitted differ more from each other, than theſe which I have mentioned do, either with reſpect to colour or weight. *Wallerius* ſpeaks of a bluiſh ſlate which weighed 3300 ounces to the cubic foot; this ſort, probably, contained a large portion of iron; the bluiſh iron ſtone, called *Catſcope*, weighs 3309 ounces to the cubic foot. In the ſlate quarries, ſome of the fiſſures are filled with ſpar, which has often an iron or copper pyrites adhering to it; in the very middle of the blocks of ſlate there are many little hollows, each of them big enough to hold a large hazel nut; theſe hollows are filled with clay; and in one of the quarries I ſaw a conſiderable quantity of clay fit for pipes, between two layers of ſlate.

It appears from the table, that the difference in weight between a cubic foot of the heavieſt, and a cubic foot of the lighteſt of the fourteen ſorts of ſlate there enumerated, is only 65 ounces; or about one forty third part of the weight of a cubic foot of the heavieſt ſort; hence, ſuppoſing the different ſorts of ſlate to be ſplit to equal thickneſſes, the difference of the weights ſuſtained by the timbers of ſlated buildings, is very inconſiderable, whatever ſort of ſlate be uſed.

That ſort of ſlate, other circumſtances being the ſame, is eſteemed the beſt, which imbibes the leaſt water; for the imbibed water not only increaſes the weight of the covering, but in froſty weather, being converted into ice, it ſwells and ſhivers the ſlate. This effect of froſt is very ſenſible in tiled, but it is ſcarcely felt in ſlated houſes; for good ſlate imbibes very little water; and when tiles are well glazed, they are rendered in ſome meaſure, with reſpect to this point, ſimilar to ſlate.—I took a piece of Weſtmoreland ſlate, and a piece of a common tile, and weighed each of them carefully; the ſurface of each was about 30 ſquare inches; both the pieces were immerſed in water for ten minutes, and then taken out and weighed, as ſoon as they had ceaſed to drip; the tile had imbibed above a ſeventh part of its weight of water; and the ſlate had not imbibed a two hundredth part of its weight; indeed the wetting of the ſlate was merely ſuperficial. I placed both the wet pieces before the fire; in a quarter of an hour the ſlate was become quite dry, and of the ſame weight it had before it was put into the water; but the tile had loſt only about 12 grains of the water it had imbibed, which was as near as could be expected the very quantity which had been ſpread over its ſurface; for it was the quantity which had been imbibed by the ſlate, the ſurface of which was equal to that of the tile: the tile was left to dry in a room heated to 60°, and it did not loſe all the water it had imbibed in leſs than ſix days.

Some of our old buildings in Cambridge are covered with a whitiſh kind of ſlate, which is dug at *Collyweſton* in *Northamptonſhire*; this ſlate is, as to its principal component part, a calcareous earth, very ſimilar to the *Barneck* ſtone of which *Peterborough* cathedral and part of *King's Chapel* in Cambridge are built; and the ſtratum of ſtone, which may be ſeen on the road ſide between *Oxford* and *Burford*, and from thence towards *Glouceſter*, is not very different from it. This Collyweſton ſlate imbibes more water, and retains it for a longer time, than the Weſtmoreland ſlate does; but it does not imbibe half ſo much, nor retain it a quarter of the time, that a common tile does. The manner of its being formed into ſlate deſerves to be noticed. Large blocks are dug in autumn, and theſe blocks being placed in a poſition different from that they had in the quarry, the rain inſinuates itſelf between the layers of which the ſtone is compoſed; and in froſty weather the water ſwelling, as it becomes ice, ſplits the block of ſtone into plates of a proper thickneſs. We have a ſtone which is of a calcareous nature, and is called *clunch*, in this neighbourhood; it is ſoft and eaſily wrought, and when properly placed in a building is very durable; but if the poſition of the ſtone in the building, be different from what it was in the quarry, that is, if the ſide of the ſtone which in the quarry was parallel to the horizon, be either perpendicular, or inclined to it, in the building, it ſoon cracks and moulders away; and I am not certain but the durability of *Portland* ſtone itſelf, may have ſome dependence on its poſition in a building, being ſimilar to or diſſimilar from that, which it had in the quarry: and this may be one reaſon why we ſee in *Black Friars* bridge, and in ſome houſes and other edifices in London, which are made of Portland ſtone, a few ſtones which are more decayed than the reſt.

The ſtone or metal, as the workmen call it, of which the Weſtmoreland ſlate is made, though it does not ſplit equally in all directions, yet is it not formed into ſlate by the action of the froſt, as the calcareous ſlate of Northamptonſhire is: it is dug, or blaſted from the quarry in large maſſes, and ſplit by workmen furniſhed with tools ſuited to the purpoſe. Though the weights of equal bulks of the different ſorts of Weſtmoreland ſlate, do not differ much from each other, yet all the ſorts are not equally capable of being ſplit to an equal degree of thinneſs: the quality of the ſlate varies alſo with the depth of the quarry, that being the beſt which is raiſed from the greateſt depth.

We learn from Dr. *Borlaſe* *, that the gray blue ſlate of *Denyball* in Cornwall, weighs only 2512 ounces to the cubic foot, which is greatly leſs than the lighteſt of the Weſtmoreland ſlates, that I have met with. This Corniſh ſlate for its lightneſs and enduring weather (though I have no reaſon to think that in the laſt particular it excels the Weſtmoreland ſlate) is generally preferred to any ſlate in Great Britain, and "is perhaps the fineſt in the world †." This ſort is ſplit to about the thinneſs of an eighth of an inch, when it is applied to the covering of a roof, and it then weighs rather more than 26 ounces to the ſquare foot: the very pale blue, fine grained ſlate from near Ambleſide, when an eighth of an inch in thickneſs, weighs about 28 ounces to the ſquare foot, or about 2 ounces more than the Corniſh ſlate here ſpoken of.

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* Hiſt. Corn. p. 93.

† Woodward's Cat. Vol. II. p. 5.

The fineſt ſort of blue ſlate is ſold at Kendale for 3*s.* 6*d.* a load, which comes to 1£. 15*s.* a ton, the load weighing two hundred weight. The coarſeſt may be had for 2*s.* 4*d.* a load, or 1£. 3*s.* 4*d.* a ton. Thirteen loads of the fineſt ſort will cover 42 ſquare yards of roof, and eighteen loads of the coarſeſt will cover the ſame ſpace: ſo that there is half a ton leſs weight put upon 42 ſquare yards of roof when the fineſt ſlate is uſed, than if it was covered with the coarſeſt kind, and the difference of the expence of the material is only 3*s.* 6*d.* To balance in ſome meaſure the advantage ariſing from the lightneſs of the fineſt ſlate, it muſt be remarked, that it owes its lightneſs, not ſo much to any diverſity in the component parts of the ſtone from which it is ſplit, as to the thinneſs to which the workmen reduce it; and it is not able to reſiſt violent winds ſo well as that which is heavier.

A covering of lead is heavier than a covering of fine ſlate, but not greatly ſo. Thirteen loads or 26 hundred weight of fine ſlate will cover, as has been obſerved, 42 ſquare yards: when plumbers caſt ſheet lead for covering of houſes or churches, they ſeldom run it thinner than to about 7 pounds to the ſquare foot. On the *ſouth* ſide of a building, they make, or ſhould make, the lead a pound in a ſquare foot thicker, than when it is uſed in places not expoſed to the meridian ſun; for the power of the ſun in calcining lead is very great: in the torrid zone, a lead covering of the ordinary thickneſs will not laſt above five or ſix years, before it is calcined into a white pellicle reſembling white lead. In a ſheet of *caſt* lead there is a great inequality in the thickneſs of the ſeveral parts of it; if the thinneſt part weighs 7 lb. to the ſquare foot, the thickeſt part will often weigh 9 lb.; let it be ſuppoſed then, that a ſheet of caſt lead, the thinneſt part of which weighs 7 lb., weighs at a medium 8 lb. to the ſquare foot; then will a ſquare yard, or nine ſquare feet, weigh 72 pounds, and 42 ſquare yards will weigh 3024 pounds, or 27 hundred weight; which is one hundred weight more than the weight of the ſlate. But this is not the whole weight of the lead which is requiſite to cover 42 ſquare yards, an addition is to be made to it, equal to the weight of the lead which is uſed in lapping one ſheet over another. *Milled* lead may be not only *rolled* out to a greater thinneſs, than ſheet lead can poſſibly be *caſt* to, but it has alſo a much greater uniformity of thickneſs, than caſt lead. The plumbers ſay, that milled lead may indeed form a lighter and more uniform covering than ſheet lead, but that it will not laſt ſo long. I know not how that may be, but the milled lead company, near 100 years ago, offered to enter into a covenant to keep a covering of their milled lead of 7 lb. to the ſquare foot, in good and conſtant repair, for a term of 41 years, at 5*s.* a year, for every covering of 100£. in value. A term of 41 years is not a quarter of the period, which many coverings of Weſtmoreland ſlate have laſted with very inconſiderable repairs; and as a ton of ſlate will cover a larger ſurface than a ton of lead, and does not coſt in any part of the kingdom, to which there is water carriage, one fourth of the price of the lead, it ſeems as if it might be generally uſed inſtead of lead with very great advantage.

In *Ruſſia* they cover their houſes with iron, and in *Sweden* with copper; and ſome architects have been fond of introducing the uſe of copper covering into Great Britain. I have no knowledge of the duration of a copper covering; but I ſhould conjecture, from the thinneſs of the copper which is uſed for the purpoſe, that it would not laſt ſo long as ſlate; it has certainly the advantage of being much lighter, and where there is danger of ſtraining the walls by the weight of timber in the roof, it may be uſed with great advantage. All the plates of copper of four feet in length and two in breadth, which weigh leſs than 10 pounds, are called thatch copper, from their uſe in covering buildings; theſe plates are in general a penny in the pound weight dearer than the thicker plates, on account of the greater trouble in rolling them. A ſquare foot of thatch copper

per does not weigh quite 20 ounces, and hence 42 ſquare yards of ſuch copper will not weigh much above four hundred weight, and its thickneſs will be about the fortieth part of an inch.

A common Cambridge tile weighed 37 ounces; they uſe at a medium 700 tiles for covering 100 ſquare feet, or above 2½ tons of tile to 42 ſquare yards. Hence, without including the weight of what is uſed in lapping over, &c., when a building is covered with copper or lead, it will follow, from what has been ſaid, that 42 ſquare yards of building will be covered by

Copper -	4 hundred weight.
Fine ſlate -	26
Lead -	27
Coarſer ſlate	36
Tile -	54

The Northamptonſhire ſlate (not to ſpeak of ſeveral other ſorts) not being ſold by weight like that from Weſtmoreland, nor having a definite ſize like tile, it is not an eaſy matter to eſtimate the weight of it which is requiſite to cover 42 ſquare yards, or any other definite ſurface; a cubic foot of it weighs 2592 ounces, ſo that it is, bulk for bulk, near one twentieth part lighter than the lighteſt of the Weſtmoreland ſlate, but its thickneſs is, at a medium, much greater; hence its weight in a definite ſurface of roof, is greater, I apprehend, than that of the coarſeſt kind of Weſtmoreland ſlate; its durability is very conſiderable, as may be collected from the time it has laſted on ſome of our college buildings.

A common ſlate is a very compound

body; it contains iron, to which it owes its colour, calcareous earth, magneſia, flint earth, and clay combined in different proportions in the different ſorts. Mr. *Kirwan* is the only perſon who has analyzed any of the ſorts: the ſort he analyzed was the bluiſh purple, which is principally uſed in London, and which is brought thither from Devonſhire and Wales. A cubic foot of it weighed 2876 ounces, which is near 150 ounces more than the weight of a cubic foot of the fineſt ſort of Weſtmoreland ſlate: he found that 100 grains of it conſiſted of about 46 grains of flint, 26 of clay, 8 of magneſia, 4 of calcareous earth, and 14 of iron, and that it loſt, by being heated red hot, 2 grains.

I took a piece of *Throng Crag* ſlate,

which is the ſort *Newgate* is covered with, weighing 446 grains, and heated it red hot; it had loſt 4 grains of its weight, by that degree of heat; I kept it for half an hour in a red heat, it had then loſt 38 grains of its original weight; I continued it in the ſame heat for three hours more, and it had then loſt 43 grains, or near one tenth part of its weight. I calcined the bluiſh green *Ambleſide ſlate* in a degree of heat, which would have reduced the ſame weight of calcareous earth to lime; 446 grains of it loſt 41 grains; on a repetition of the experiment, I found that 446 grains had loſt 42. The ſame weight of *White Moſs* ſlate, treated in the ſame way, loſt 42 grains; and the ſame weight of ſlate from *Coniſton* loſt 44 grains. I tried ſeveral other ſlates in the ſame manner, and the general concluſion is, — that Weſtmoreland ſlate loſes, by being calcined in a red heat for ſeveral hours, about one tenth part of its weight.

All theſe ſlates, when reduced to a fine powder, are acted upon with great violence by acids, a conſiderable portion of fixed air is diſcharged, and a calcareous earth is diſſolved in the acid. I poured a diluted acid of ſea ſalt on 446 grains of Throng Crag ſlate in powder, 30 grains of fixed air eſcaped during the ſolution. We have ſeen that the ſame weight of the ſame ſort of ſlate loſt by calcination 43 grains, the difference is 13 grains; but whether theſe 13 grains are water, or a part of the earthy ſubſtance of the ſlate which is driven off during the calcination, is what I do not pretend to determine.

The calcined ſlate being put into water, there is formed in a few days a ſtrong lime water; this water depoſits, as other lime water does, an earth which efferveſces with an acid. It has been proved, in the Eſſay on calcareous earths, that 20 parts of calcareous earth contain about 9 parts of fixed air; and hence, as the ſlate is ſuppoſed to loſe about one tenth of its weight of fixed air by calcination, the crude calcareous earth (ſuppoſing the air to have proceeded *ſolely* from calcareous earth) which it contains, may amount to about 22 parts in an 100 of ſlate. I have met with ſome ſlate, much reſembling the Weſtmoreland ſlate, which does not loſe above a twenty-fifth part of its weight by calcination. Beds of limeſtone are generally incumbent on the beds of ſlate; and, however philoſophers may account for the original formation of theſe beds, it may eaſily be admitted, that the component parts of the upper ſtratum may be mixed with thoſe of the lower; and if the fact was examined, I think, it would be found, that the ſlate is more mixed with calcareous earth, the nearer it approaches to the limeſtone ſtratum.

I diſtilled five ounces of *White Moſs ſlate* in a very ſtrong fire for three hours; there came over a great deal of air, but ſcarce a drop of water, (though it is poſſible that in this, and other diſtillations of a like kind, ſome water may eſcape with the air,) and there was a ſlight ſmell of ſulphur.

The maſs remaining in the retort was reduced into a black cellular glaſs, of ſo hard a texture, that it ſtruck fire with ſteel; it adhered ſo much to the retort, that I could not ſeparate it ſo perfectly as to be able to ſee what loſs of weight the ſlate had ſuffered by being vitrified. We have no coal in Weſtmoreland, except a little of a bad quality near *Shap*, or *glaſs-houſes* might be eſtabliſhed at the *ſlate quarries* with great proſpect of advantage; for though the materials of which *bottle* glaſs is made, coſt but little in any country, yet there they would coſt nothing. Very good glaſs might, *probably*, be made from the ſlate alone, for the cellular texture would diſappear, either on keeping the glaſs longer in the fire, or on re-melting it; but *certainly* it might be made from the ſlate mixed with fern aſhes, or with kelp aſhes, or with other ſubſtances containing fixed alkali: — this hint, I hope, will not be given in vain.

Pliny ſpeaks of a kind of *foſſil glaſs*, which one *Obſidius*, he ſays, found out in *Ethiopia*; it was of a black colour and ſometimes tranſparent: and *Herodotus*, in the third book of his hiſtory, reports, that the *Ethiopians* had a cuſtom of drying the carcaſes of their dead, of covering them when dried with gypſum, or plaſter of Paris (γυψωσαντες), of painting their portraits on the plaſter, and, laſtly, of depoſiting them in cells made of tranſparent glaſs, which in that country was dug in great plenty. This account has been looked upon as fabulous; becauſe glaſs, it is ſaid, is not a natural but a factitious ſubſtance; and the learned, for the ſame reaſon, have been much puzzled about Pliny's *lapis Obſidianus*, or, as ſome will have it, *opſianus*, on account of its tranſparency. The word (ὑελȣ in Herodotus) here rendered glaſs, may, perhaps, denote *lapis ſpecularis*; which is now, and has in all ages, been dug out of the earth, and is found frequently along with gypſum; I do not believe, indeed, that it has been ever found in pieces large enough to make coffins of: but, ſuppoſing it to mean glaſs ſtrictly ſo called, I ſee no difficulty at all in admitting the exiſtence of foſſil glaſs. A ſubterraneous fire, of a proper degree of ſtrength, would convert a ſtratum of Weſtmoreland ſlate into a vitreous maſs of a black colour.

Nor is Weſtmoreland ſlate the only ſubſtance which might be converted into foſſil glaſs; the gray *rag ſtone*, before mentioned *, admits a ſimilar change; ſo does the blue *whin-ſtone*, and the Derbyſhire *toadſtone*, and ſeveral other ſorts of ſtones. The reaſon of the fuſibility of theſe ſtones is explained, in ſome meaſure, by an experiment related in another place †; it is there proved, that two ſpecies of earth, ſeparately unvitrifiable, may be vitrified when mixed together; the two earths there mentioned are clay and chalk, but the obſervation is true concerning ſome other earths. Now the ſlate and ſtones, of which we have been ſpeaking, are all compound bodies, conſiſting of ſiliceous, argillaceous, calcareous earths, &c.

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* Pag. 60. † Vol. II. p. 183.

combined in different proportions, and the fuſibility ariſes from their mixture.

Some reaſons have been given * (though I do not think they prove the point) for conſidering the Derbyſhire *toadſtone* as a ſpecies of *lava*, which has undergone a ſemi-vitrification; however that may be, I have met with pebbles (rounded, probably, by ante-diluvian waters) which reſembled toadſtone in colour, weight, and conſiſtence, in the *gravel-pits of Cambridgeſhire*; in the *marl-pits of Cheſhire*; in the clay which is ſituated under the *grit*, and above the *ſhale* of *Derbyſhire*; on the ſides of the mountains, and in the beds of the rivers of *Weſtmoreland:* and I doubt not ſimilar ones will be detected, by future obſervation, in many other places.— The following table coſt me ſome trouble in the making, I am unwilling that it ſhould be loſt, and there are ſome readers who will be gratified with a ſight of it.

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* Vol. III. p. 299.

Weight of a cubic foot of different ſorts of ſtones.

N.	oz.	18	2688
1	2999	19	2682
2	2936	20	2681
3	2927	21	2681
4	2921	22	2675
5	2907	23	2669
6	2852	24	2659
7	2821	25	2657
8	2800	26	2653
9	2797	27	2651
10	2778	28	2643
11	2776	29	2631
12	2770	30	2625
13	2760	31	2605
14	2710	32	2593
15	2708	33	2556
16	2695	34	2399
17	2690	35	2277

No. 1. *Guernſey* pebble, from the pavement of one of the ſtreets of Weſtminſter. 2. I met with this ſtone on *Hale-Fell*, near *Beetham*, in *Weſtmoreland*; it is of a dark brown colour, and admits a very fine poliſh, but it is not calcareous. The block was ſome tons in weight, and ſituated on the ſurface of the earth, every where ſurrounded with limeſtone rocks; I think it was a block of *baſaltes*, in which many cryſtals of black *ſhoerl* were to be ſeen. 3. Dark gray cobble, from the gravel-pits near *Cambridge:* it much reſembles No. 4. Dark gray *toadſtone* from Derbyſhire; free from thoſe ſparry ſpecks (which in mouldering away by expoſure to the air, often leave the toadſtone as if it was worm-eaten) and ſtriking fire with ſteel. 5. Lead coloured cobble, with black ſpecks, and of a vitreous texture from *Hearſam Head*, in *Weſtmoreland.* Hearſam Head is a hill compoſed of calcareous ſtrata; but there are found on its ſurface, and in other parts of the county, detached round pieces of a blue rag-ſtone, of granite, and of a very hard compound ſtone, called by the maſons of the country *callierde*; probably ſo denominated either from the earth (erde) of which it is compoſed, reſembling flint (*caillou*) in hardneſs, or from its being compoſed of different ſorts of earth coagulated (*caillè*) together. Mineraliſts, I think, would claſs the *callierdes*, for they are not all of the ſame kind, amongſt the *porphyries*, *hornſtones*, &c. 6. Similar to toadſtone in texture, but darker in colour, from a marl-pit near *Tabley*, in Cheſhire. 7. Much the ſame as the preceding, a large block found in a field near the mills at *Millthrop*, in Weſtmoreland. I do not venture to call theſe two laſt ſtones volcanic productions, yet the ſurfaces of them looked as if they had been formed by the cooling of the maſs. 8. Round toadſtone pebble, from a bed of clay under the *grit* ſtone in Derbyſhire; I write this only from recollection of its appearance; I may have miſtaken a blackiſh limeſtone for toadſtone. 9. Purple ſlate, *Kentmere*, near Kendale; the heavieſt of any of the Weſtmoreland ſlates, but not ſo heavy as the purple ſlate uſed in London. 10. A callierde with a deep green ground, and ſpecks of a lighter green, from the *ſea ſhore* near *Lancaſter*.

caſter. I have ſeen theſe callierdes in various other parts of *Great Britain*, but I do not know whether we have any ſtrata in the *Iſland* which could have furniſhed them. 11. A greeniſh cobble, of an uniform texture, gravel-pit in the road from *Cockeran* to Lancaſter. 12. Like No. 10. marl pit, Cheſhire. 13. Blue *whin-ſtone* from *Scotland*; in a fire which would convert an equal bulk of marble to lime, a ton of whin-ſtone would loſe 2½ hundred weight. 14. Greeniſh cobble, *Wierſide*, Lancaſhire: this and No. 11. have ſome reſemblance to Weſtmoreland ſlate, but I do not know where the ſtratum is ſituated that has furniſhed theſe detached pieces. 15. Blue rag-ſtone, foreſt near *Mansfield*. 16. *Granite* from *Aberdeen*. A cubic foot of *Guernſey* pebble (No. 1.) contains, it is evident, above 300 ounces of matter more than is contained in a cubic foot of *Aberdeen* granite; but from that circumſtance alone it muſt not be inferred, that a pavement made with Guernſey pebbles, will laſt longer than one made with Aberdeen granite: for the durability of a body expoſed to friction, does not depend ſo much on the number of particles which enter into its compoſition, as on its hardneſs, or firm adheſion of its parts. But in bodies equally hard, that will laſt the longeſt which contains the greateſt quantity of matter in a definite bulk; and hence, ſuppoſing the Guernſey ſtone to be only as hard as the Aberdeen granite, it muſt laſt longer when expoſed in the ſtreets to the friction of the carriage wheels; on inquiring into the fact, a paviour told me, — that the Guernſey pavement was a very bad pavement for a poor man — becauſe it ſeldom wanted repairing. 17. *Gray blue rag-ſtone*, Weſtmoreland. 18. The ſame after being calcined to a red colour. 19. Gray rag-ſtone from *Ilvay* crag, near Millthrop. 20. The ſame calcined to a red colour.—Theſe rag-ſtones, I apprehend, loſe ſomewhat of their weight by calcination, but, their bulk being diminiſhed in the ſame proportion, their denſity or ſpecific gravity remains nearly unaltered; in a ſtronger fire they are changed into a blackiſh glaſs. 21. *Shale-bind*. This is the name of a ſtratum, conſiſting principally of calcareous earth impregnated with bitumen, which is ſituated both above and below the beds of *ſhale* in Derbyſhire. The *bind* is various in thickneſs from a few inches to ſome feet: one ſort of it is called by the miners *treacle bind*, from their finding lodged in its cavities a bitumen of the colour and conſiſtence of treacle: this bitumen is moſt abundant where there is the greateſt quantity of ſhale incumbent on the bind. There are in the ſtratum of bind many round ſtones called, probably from the rotundity of their figure, *boulders*; ſome of which weigh only a few ounces, other half a ton. Whether all round ſtones, met with in the ſtrata of the earth, or upon its ſurface, have received their figure from the action of water is uncertain; but that many of them have, the ſituation in which they are found, will not ſuffer us to doubt. Not far from *Pontypool* there is a large mountain, the bottom of which is waſhed by the river *Uſk*; this mountain contains coal and iron ſtone. At *Newport* a conſiderable trade is carried on with coal, which has been waſhed from the ſides of this and other mountains by the river: the coal is found in the channel of the river, in round, flat, ſmooth pieces; ſo perfectly reſembling in ſhape river pebbles, that they clearly indicate the manner in which theſe pebbles have been formed. 22. What ſome call white toadſtone, *Youlgrave*, Derbyſhire. 23. Brown *quartz* pebble, from the foreſt between *Mansfield* and Newark. 24. Black pebble with red ſpots, ſame place. 25. Rediſh rag-ſtone, *Helm-End*, near Kendale. 26. *Pennarth* limeſtone, waſhed in large cobbles from the clifts on the *Welch* ſide of *Briſtol* channel; the lime made from it is highly eſteemed in that country from its ſetting under water; it is called *lion* lime (perhaps *lien*) from its binding quality: the ſtone is of a gray colour, and, beſides the proper earth of lime, contains a large proportion of clay and iron. 27. Tranſparent white quartz, gravel-pits, near Cambridge. 28. Tranſparent white quartz, foreſt about Mansfield. 29. White opake quartz, ſame place. The cryſtals, called *Briſtol ſtone*, are eſteemed the pureſt ſort of quartz. It is commonly known that two pieces of quartz, when rubbed together in the dark, emit a phoſphoric light, accompanied with a ſtrong ſmell. The difference between quartz and common flint, conſiſts not ſo much in the colour, for both quartz and flint are of various colours, as in this, that quartz (though it be not perhaps an abſolutely pure ſiliceous earth) contains a leſs proportion of *clay* and *calcareous* earth, than flint does. I have obſerved on the ſea coaſt at *Yarmouth*, quartz pebbles beginning to be decompoſed, and verging towards the ſtate of a white argillaceous earth: moſt of the ſand in every part of the world conſiſts of quartz or flint in powder; and, as matter is infinitely diviſible, the imagination can ſet no bounds to the minuteneſs of the grains of ſand; but I have ſometimes doubted, whether, after they are reduced below a certain ſtandard, they may not conſtitute ſome other ſpecies of earth. 30. *Granite*, from the *marl-pits* in Cheſhire. The roads in many parts of *Lancaſhire* and *Cheſhire* are paved with granite, and other hard round pebbles, which are found in their marl-pits, or fetched from the Welch coaſt; the pavement coſts a thouſand, or twelve hundred pounds a mile in making. 31. Granite, from a large block near *Dallam Tower*, in Weſtmoreland. Large maſſes of a *reddiſh* granite are found on the ſides of the hills, in the vallies, and in the beds of the rivers, not only about *Shap*, but in various other parts of Weſtmoreland. It is a queſtion of no ſmall difficulty to account for the manner of their being placed there: ſome will have it that they have been left there by water; and others think they have been ejected from the bowels of the earth by the force of a volcanic exploſion. *Beds* of granite are found in many, and *detached pieces* in moſt parts of *Europe*. The higheſt mountains on the globe are formed from the loweſt ſtrata of the earth, and the tops of the higheſt mountains are compoſed of granite; and hence granite mountains are called *primitive* mountains; inaſmuch as the ſtrata of granite, being ſituated below the ſtrata of rag-ſtone, ſhale, limeſtone, &c. of which many other (called *ſecondary*) mountains are compoſed, muſt have exiſted before them. All granites are compound bodies, they conſiſt of two, of three, of four, or of five diſtinct ſubſtances denominated, by writers of ſyſtems of mineralogy, *quartz—felt ſpar—mica—ſteatites*—and *ſhoerl.* It belongs to the higher chemiſtry to analyze the component parts of granite, to explain their origin, and the manner of their combination; and to enquire whether they are ſubject to a ſpontaneous ſeparation, and what kinds of ſubſtances will ariſe from a ſtratum of decompoſed granite. 32. Red granite, from a Cheſhire marl-pit, reſembling the red oriental granite. All the varieties of *red* and *gray* granites, which may be ſeen in the works of the ancients remaining in *Italy*, might be found, I believe, in different parts of Great Britain; without any thought of making a collection of them, I have accidentally picked up near twenty different ſorts. 33. *Shale* from Derbyſhire. 34. Quartz, white, with many ſmall irregular holes: there are quarries of it in France, and we import mill-ſtones made of it. The holes are remarkable; it looks as if the ſtone had been worm-eaten; but the holes are formed, I conjecture, from ſome of the principles of the ſtone being decayed,

cayed, whilſt the reſt remain intire. I have frequently ſeen pieces of *rag-ſtone*, and even ſome ſorts of *granite*, which have been externally, and indeed to a very ſenſible depth below the ſurface, ſtudded with little holes from the ſame cauſe. 35. A *cellular lava*, of which the mill-ſtones, called *Rheniſh*, are made; it is very porous, of a brown dirty colour, and in external appearance like a piece of coak, but it is hard enough to ſtrike fire with ſteel. *Strabo*, in ſpeaking of an eruption of mount *Etna*, very accurately deſcribes the formation of this ſpecies of ſtone, which in his time was applied to the ſame purpoſe it is now; I quote the Latin tranſlation of the paſſage — *lapide in crateribus colliquato ac deinde ſurſum egeſto, humor vertici ſuperfuſus cœnum eſt nigrum,*

grum, per montem deorſum fluens: deinde ubi concrevit, lapis fit molaris *.

The analyzing the various ſtones which are met with, either in large beds in the earth, or in detached pieces at the bottoms of the rivers, or on the ſea coaſts of the kingdom; and the lodging the ſpecimens in ſome public Receptacle, where they might be ſeen by the *Students in Natural Hiſtory*, might occupy very uſefully the leiſure of a philoſophical Chemiſt. He would find a far greater variety of *jaſpers*, *porphyries*, *granites*, *flints*, *limeſtones*, *ſlates*, *lavas*, &c. than at the firſt view of the ſubject he would probably expect. Experimental inveſtigations of this ſort, made with ability and caution, in different parts of the world, are the only ſure foundations on which we can ever hope to build any probable ſyſtem concerning the formation of mountains, the antiquity of the preſent form of the globe, and the cauſes of the viciſſitudes which it has undergone. It is the proper province of natural philoſophy to explore *ſecondary cauſes*; they are the ſteps on which the mind of man aſcends from Earth to Heaven: for the more diſtinctly we apprehend the number and connexion of the ſecondary cauſes operating in this little ſyſtem which is ſubmitted to our view, the more certainly ſhall we perceive the neceſſity of their ultimately depending, like the links of *Homer's* chain, on a FIRST.

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* L. VI.

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